An Assessment of Water Measurement Techniques Used in the Vancouver Island Salmonid Enhancement Projects

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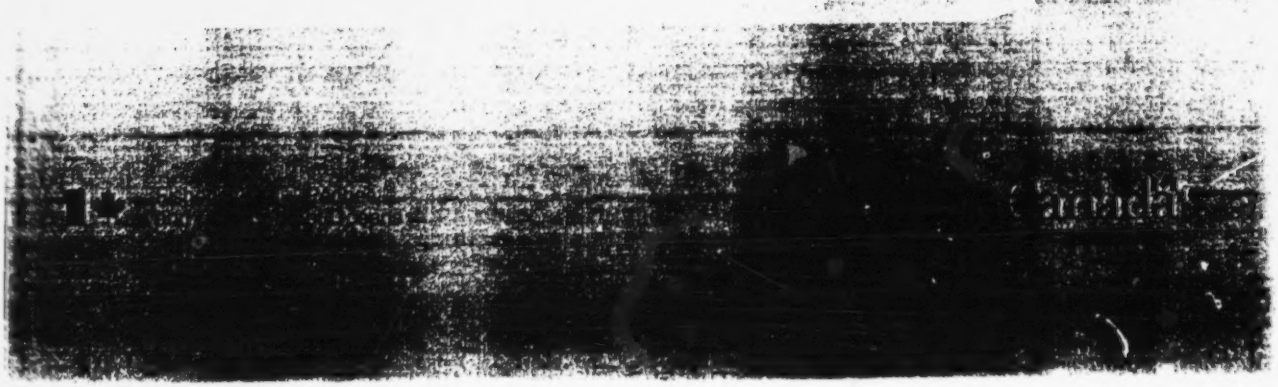
December, 1983

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 1734



2008-06008/

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c Minister of Supply and Services Canada 1982
Cat. No. Fs 97-4/ 1734 ISSN 0706-6473

Correct citation for this publication:

Lukyn, Brian V. 1982. An Assessment of Water Measurement Techniques Used in in the Vancouver Island Salmonid Enhancement Projects. CAN. MS Rep. Fish. Aquat. Sci.1734:X+75p.

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Abstract

Lukyn, Brian V. 1982. An Assessment of Water Measurement Techniques Used in the Vancouver Island Salmonid Enhancement Projects. CAN. MS Rep. Fish. Aquat. Sci. 1734 : X + 75 p.

This report aims at providing a catalogue of the existing types of water measurement methods used by the South Coast Salmonid Enhancement projects. It also will provide a listing of alternate devices that can be used in the measurement of water. A small section on field work performed followed by recommendations and conclusions will also be included.

Le présent rapport vise l'établissement d'un répertoire des méthodes de mesurage de l'eau utilisées dans le cadre des projets de mise en valeur des salmonidés de la côte sud. On y trouve également une liste de mécanismes de rechange qui peuvent servir au mesurage de l'eau. Le rapport comprend une courte section sur le travail réalisé jusqu'à maintenant sur le terrain, laquelle est suivie des recommandations et des conclusions.

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AN ASSESSMENT OF WATER FLOW MEASUREMENT TECHNIQUES USED IN THE VANCOUVER ISLAND SALMONID ENHANCEMENT PROJECTS

1.0 INTRODUCTION

1.1 Purpose of water measurement

Water is the medium through which eggs, alevins and juvenile fish receive dissolved atmospheric oxygen. Water also removes the waste products of metabolism; the term metabolism refers to the vital processes involved in the release of body energy, the building and repair of body tissues, and the excretion of waste materials.[1]

The ability to measure waterflow has many implications whether biological, political, economical, etc. The purpose of this report is to provide a list of existing and available methods and devices used in the measurement of water throughout the south coast facilities.

Water is moved through the various facilities by two systems. The first is the closed conduit or pipeline system. Pipelines are used to move large flows such as from river intakes or small flows as found in incubation. Pipelines also are used to carry discharge water as is found in rearing tubs, intermediate troughs, etc.

The second system is that of the open channel, examples of open channels are raceways, burrows ponds, earthen channels. Outflow from these containers is often accomplished by stoplog weir structures, which are built across the open channels to control the water height.

Three points for flow measurement in the salmonid containers are:

(1) the point of inflow, generally a pipeline device to measure flow

(2) in the open channel itself, between the points of inflow and outflow

(3) at the actual discharge point or outflow.

This report categorizes the existing and available devices according to whether they are used as inflow or outflow systems. The second point of measurement as described in the preceding paragraph would pertain to Gurley metering in most instances, however, specialized dye methods are available which will be dealt with later on in this report. Gurley meters, most commonly used where there is no other system available will fall under the outflow heading.

2.0 OVERVIEW

2.1 Overview of Existing Methods

Tables 1 to 8 outline for each facility what devices and methods are used to measure waterflow through the various salmonid containers. The tables are set up according to whether these measurements are taken at the point of inflow or outflow. The water entering a system should equal the water leaving the system, thus providing points for cross checking flow measurement. Leakage can occur in earthen and/or gravel channels and this will be discussed later on. As mentioned in the introduction of this report, measurement can be taken in the open channel between the points of inflow and outflow (Figure 2) by Gurley meters.

Flow ranges encountered over the different types of rearing containers used in the South Coast Unit vary from 4-20 lpm for Heath tray incubation systems to 153,000 lpm (approx.) for spawning channels.

2.2 Existing Devices

The tables list the devices and methods used to measure waterflow. The headings of inflow, outflow can be used to categorize the systems used. Water is carried to the container most often by pipeline and water is carried out or discharged by cement channels or pipelines.

The existing methods can be grouped as follows:

Inflow	Outflow
Magnetic Meter	Rectangular Contracted Weirs
Impact Tubes	Rectangular Suppressed Weirs
Rotameters	90° V Notch
Sparling Meters	Bucket Stop-watch
Ultra-Sonic Meter	
Annubar/Eagle Eye	
Bucket/Stop-watch	
Foxberg Differential Pressure Meters	

The following sections will deal with each of the above devices, their characteristics, applications, etc.

3.0 DISCUSSION OF METHODS USED

3.1 Inflow Devices

The devices used to measure inflow will be reviewed first. These devices are:

Magnetic Flow Meter
Impact Tubes
Rotameters
Sparling Meters
Ultra-Sonic Meter
Annubar/Eagle Eye
Bucket/Stop-watch
Foxberg Differential Pressure Meters

3.2 **Instrument - Fisher & Porter Magnetic Flowmeter 10D1430A/U**
Site Location - Quinsam River (aeration tower)

Principals of Operation

The Fisher and Porter magnetic flowmeter (Figure 3) is a compact, volumetric, liquid flow rate detector that utilizes as the process transducing method the characteristic of a conductive fluid to generate an induced voltage when flowing through a magnetic field. The amplitude of the voltage, thus produced is directly proportional to the flow rate of the metered fluid.[2]

The voltage available at the output is based on Faraday's law.

$$E = BLV \times 10^{-12}$$

where E = induced voltage (V)
B = flux density (T)
L = length of conductor (cm)
V = velocity of conductor (cm/s)

Since the fluid is similar to the moving conductor, output voltage is proportional to fluid velocity.[3]

General

The magnetic meter is an obstructionless system that measures flow without regard to heterogeneous consistency and is as independent of tendency to plug or foul as the pipeline in which it is mounted. With the external mounting system there is no pressure loss that occurs with intrusive type meters. The magnetic meter operates with no compensation required for fluid density and viscosity. Metering limitations are confined only to a minimum threshold of electrical conductivity inherent to the fluid being metered. The degree of fluid conductivity has no effect upon metering accuracy as long as it is greater than this minimum level. The magnetic flowmeter permits

unidirectional flow measurement in either direction without changing physical orientation, instrument adaptors or control operations of any sort.[4]

Specifications - Minimum Conductivity

Minimum allowable fluid - 5 or 20 microhms per centimeter minimum.

Flow range - .3 m/s → 9.1 m/s
Accuracy - .3 → 9.1 m/s ± 2%, .91 m/s → 9.1 m/s ± 1%

Installation

Standard meter piping connections are made by means of a modified flat or raised face flanges that conform to ANS standards in outside diameter and bolt circles.

The magnetic meter requires a convenient source of 120 volts, 50 or 60 hertz, single phase, line power complete with disconnect switch and a suitable fuse or circuit breaker. Further, if the pipeline to be metered is not in itself a good ground, a suitable earth ground must be made available in proximity to the installation site.[5]

Comments

The metering pipe should be completely filled at all times for accurate results. Since volume of flow rate is proportionally related to fluid velocity by means of constant area or diameter of the meter pipe section, a partially filled pipe incurs errors in a direct relation of the fluid area to the pipe area. Where there is a possibility of operation with a partially filled horizontal pipeline, it is recommended that the magnetic flowmeter be installed in a vertical section of that pipeline such that fluid flow moves upward.[6]

Satisfactory operation of Fisher and Porter magnetic flowmeters requires that careful attention be paid to proper grounding techniques. A good ground

is one that is in contact with the earth over a large conductive area. An excellent example of this is a cold water pipe which is buried in the earth and travels many miles in its distribution system.

Magnetic flowmeters are used by the pulp and paper industry where precise flow measurement is required. Joe Latowski (head of instrumentation at Crofton Pulp and Paper) has stated "that magnetic flowmeters are one of the best systems available" (pers. comm.).

The major disadvantage of magnetic flowmeters is their high initial cost, which to date is approximately $6,000. However, the meters are reliable because they have no moving parts and accuracy is very good.

3.3 **Instrument - Fisher & Porter Impact Tubes, Series 10F1031**
Site - Quinsam River (incubation flows)

Principles of Operation

The flow of liquid through the meter is controlled by a spring loaded shut-off valve. When the knob on the front of the meter is pushed in, the meter is in service and the flow rate of liquid flowing through the pipeline can be read. To read the meter, observe the horizontal center line of the ball float on the scale tube. Upon release of the knob the fluid is shut-off to maintain meter cleanliness. With the flow shut off, the meter can be partially disassembled to clean the meter and scale tubes as well as the range orifice.[7]

General

The Fisher and Porter impact meter requires only one connection to the pipeline. The meter may be installed in a horizontal, vertical or sloped run of pipeline. Flow through the meter is normally shut off as continuous indication of flow rate is not required. Meter capacity can be changed relatively easily by changing tubes and floats.

Specifications

Four scales for different sized pipes ranging from 100 mm to 200 mm.

Installation

The installation of the impact meter is simple and easy to perform. The meter may be placed in a vertical, horizontal or sloped run of pipe, however the meter must be vertical and plumb. Mount the meter in at least 10 diameters (preferably 20 for 3.8 cm pipe) of straight run. Valves and elbows in the pipeline create disturbances in the flow pattern that should be avoided.

The meter threads into a 1.27 cm NPT bushing that is welded into the pipeline. After the bushing is welded into the pipeline, the meter is attached as indicated in Figure 5. To remove the adaptor bushing from the impact tube, back off the meter gland nut assemble the adaptor bushing to the pipeline bushing using sealing tape or pipe dope on this joint to prevent leakage. Then mount the meter and hold it in a vertical position. Tighten the gland nut to lock the meter in position.

Comments

The Fisher and Porter impact meters used for measuring incubation flows at Quinsam River are prone to fouling. According to the manufacturer's bulletin they are capable of being cleaned out while installed.

The next section will deal with Pako Sho-Flo meters which are also used to measure incubation flows. These meters work fine apparently and may be better suited to measure small incubation flows.

3.4 Instrument - Pako Sho-Flo Indicator (Rotameter)
Site-Robertson Creek (Incubation Flows)

Principles of Operation

Rotameters (Figure 6), variable area devices, have a linear scale readout with flow rate, and pressure drop is essentially constant at all flow rates within the meter range. A rotameter consists of a transparent tapered tube containing a float. The tapered tube must sit vertically, and the fluid enters the meter at the lower, and smallest diameter, end of the tube. Drag forces caused by the moving fluid lift the float until they just balance the gravitational forces resisting the upward motion. The float is essentially floating in the moving fluid column. A linear scale formed on the tube exterior allows the position of the flat to be read accurately. Mathematically flow through a rotameter can be expressed as follows:

$$Q = A_1 C \left[\frac{2g V_2 - (p_2 - p_1)}{A_2 p_1} \right]^{1/2}$$

where: Q = flow rate (volumetric) (cm^3/s)
A = area (cm^2)
C = discharge coefficient
V = volume
g = acceleration of gravity (cm/s^2)
p = density (g/cm^3)

Subscript 1 refers to the liquid
Subscript 2 refers to the float.[8]

General

Pako Sho-Flo rotameters have a linear scale over the range of the meter, with a constant pressure drop at all flow rates.[9] Meter capacity can be

changed relatively easily by changing tubes and floats, as in the case of the impact tube design. Sho-Flo indicators have no moving parts except the free moving float which indicates rate. A control valve shuts the flow to the rotameter off when it is not being used.

Specifications

Range - 4 - 16 lpm
Float - ball type

Installation

The Pako Sho-Flo must be installed vertically for proper operation. Mounting is accomplished by the use of plastic adaptors which are seated firmly into the pipeline.

Comments

The Pako Sho-Flo has been used successfully to measure incubation flows to the heath stacks at Robertson Creek. The important difference between the impact tube and rotameter design is that in the rotameter, water flows through the meter in one straight path. In the impact tube, water enters the meter travels upward to the top, spills over the top into a return path enclosed by the scale tube. The downward flow is then directed through passages in the inlet fitting and shut-off valve assembly and returned to the pipeline. The passages in the inlet fitting which facilitate discharge are small and susceptible to clogging by silt, etc. The Pako Sho-Flo rotameter as illustrated in Figure 6 shows the path of the water, in the bottom and straight out the top of the meter, providing less chance for fouling.

3.5 Instrument - Sparling Series 500 Flowmeter

Site - Puntledge River (Aeration Tower)

Principles of Operation

The Sparling flowmeter (Figure 7) measures pulse in two directions, against and with the flow, in order to make upstream and downstream time interval measurements. These two measurements are converted into two frequencies inversely proportional to time delay. The difference between the two frequencies is proportional to flow. Electronic switches control the transducers so that they can both send and receive signals.

The signal detector examines and amplifies the received pulse. The waveforms are converted into signal levels utilized by the logic circuits to control the voltage controlled oscillators (VCO) frequencies. These frequencies are inversely proportional to the upstream/downstream transit time.

The timing generator controls the electronic switches and selects which VCO to control, i.e. VCO1 or VCO2, relative to upstream/downstream. The VCOs hold their relative frequencies between control corrections, allowing temporary or repetitive loss if signal without affecting sensor accuracy.

The Δ F circuit subtracts the two VCO frequencies to yield the differential frequency which represents flow.[10]

General

Two of the series 500 Sparling flowmeters are used in the aeration tower at the Puntledge River project to measure either penstock or river flow.

The series 500 is a completely obstructionless system. Two interrelated components compose the system: (1) the sensor consisting of a pre-calibrated fused, epoxy coated flow tube containing a pair of externally mounted electro-acoustic transducers, and (2) the transmitters or electronics package. The

transmitter can be mounted integral to the sensor or at a remote location up to 3.6 meters from the sensor.

Specifications

Flow range - maximum of 51,000 lpm
Accuracy - ± 1% of actual flow from
± 0.5% of minimum flow from

Comments

The Series 500 Sparling meter costs approximately $5,000. to $6,000., according to Dan Maclean of BCA Industrial Controls. Mr. Maclean informed me that Sparling Envirotech stopped manufacturing this particular model two years ago. The reason for this product being taken off the market he said, "was that Sparling meters are of the propeller type and the 500 was not a propeller type". Any further reasons for its discontinuation were not supplied.

The Series 500 in use at Puntledge River has not to date given any difficulty.

3.6 **Instrument - Sparling Flowmeter**
Site - Nitinat River (Models FM 103, FM 185)

Principles of Operation

FM 103

The Sparling 103 (Figure 11) is a magnetic drive, tube type, in line flowmeter. It is a propeller meter that utilizes the simple principle of the screw propeller to register the flow travel much as an automobile speedometer registers automobile travel. The 103 is improved over the 102 in that it has a magnetic drive instead of a gear system to transmit the rotation of the propeller to the totalizing head, which reads in litres per second.

FM 185

The FM 185 (Figure 12) electronic propeller flowmeter is an in line, volumetric flow measuring device. When mounted in a flowing stream they convert liquid velocity to mechanical rotation of a propeller and via an unique sensing technique measure the rotational speed of the propeller and produce a two wire 4 - 20 milliamp output and an unscaled pulse rate output proportional to the fluid velocity.[12]

General

The FM 103 Sparling magnetic drive, tube type meters are used for the groundwater pumping stations at Nitinat River. The 103 measures litres per second. The 103 is a tube type meter, that is, it comes with its own section of pipe which is installed as though it were a short length of pipe. In developing the 103 Sparling has reduced the number of moving parts in the meter, reducing potential maintenance of the meter.

The only moving part in the FM 185 electronic propeller meter is the propeller. The electronic pickup is direct from the propeller shaft, therefore the vertical shaft and gears are eliminated from the meter.

The FM 185 is to be located in the lower floor of the aeration tower at the Nitinat River project. The 185 is a saddle type meter as opposed to the tube type 103. The saddle type meters require steel welding saddles for welding to existing steel pipes.[13]

Specifications

FM 103

Pipe size - 150 mm and 200 mm
Flow range - 150 mm -- 6 to 60 lps
200 mm -- 9 to 90 lps

FM 185

Pipe size - 600 mm
Flow range - 2000 - 6000 lpm
Accuracy - 2% of actual flow

Installation

FM 103

Tube type meters are installed in line just as though they were a short length of pipe. The propeller must face the oncoming flow and in proper position, arrows cast on the meter tube and head plate will point in the direction of the flow (Figure 14).

Choose a location that assures a full pipe of water flowing at or above the minimum velocity specified for the meter, with no contractions or obstructions ahead that would produce a jet of spiralling flow into the meter. At least 5 diameters of straight pipe upstream and one diameter is recommended. A jet caused by a partially opened valve, a centrifugal pump, or a pipe contraction a short distance upstream from the meter may cause trouble.[13]

FM 185

The FM 185 is a saddle mounted meter and may be one of these types:

(1) for bolting to the pipe
(2) for welding to steel or wrought iron pipe
(3) for U-bolting to pipe or wood, concrete or asbestos cement.

The FM 185 saddle to be used at the Nitinat River project is to be welded to a 600 mm steel pipe. Cast steel saddles are supplied for welding on steel and should be tacked first, then welded in place, taking care not to overheat any part of the saddle.

Comments

FM 103, 185

Propeller meters such as the 103 and 185 are in line meters which obstruct flow by means of the propeller in order to determine volume. Anything that changes the pattern of flow approaching the meter changes the frictional resistance of the propeller and drive system, and affects the accuracy of the meter registration.

Propeller shafts are usually designed to rotate in one or more bearings. The bearing is contained in a hub and is protected from direct contact with objects in the flow. However, water can and often does enter the bearing. Some hubs trap sediment, silt or other foreign particles, and after these work into the bearing a definite added resistance to turning becomes apparent. Some propellers are therefore designed for flow through cleaning action so that particles do not permanently lodge in the bearings.[14]

Propeller bearing troubles are the most common problem and may be difficult to overcome except by means of a well planned maintenance program. Maintenance costs may be excessive if meters are in sediment laden waters. Meter size selection is also important, and many meters have been taken out of service because a larger than necessary meter was purchased and it was not able to record the usual smaller day to day flows. If possible, the meter size should be selected so that most of their operation will be in the midrange of the capability.[15]

The Sparling 103 and 185 are quite expensive to purchase, with the 103 costing approximately $6,000 and the 185 costing $4,500 (plus saddle cost). Nitinat River is a young project and the long term reliability of these meters is yet to be determined.

3.7 Instrument - Ultra/sonic Flowmeter (Model # UFT-503)

Site - Puntledge River

Principles of Operation

The ultra/sonic flowmeter is a portable device, which may be carried from pipe to pipe to measure flow. By means of a transducer placed on the outside of a pipe, the ultra/sonic meter injects ultra/sonic energy into the pipe which will bounce off the opposite wall and be returned to the transducer. Since the fluid is moving, the wave will travel slower or faster, depending on the relative direction of motion of the wave and the fluid, relative to the wave velocity in a stationary fluid. The sensor will detect the resulting phase shift which is proportional to fluid velocity. This meter then totalizes this information into a meters per second scale.

General

The invention of a device to measure flow in pipelines of varying sizes would be invaluable for use in the South Coast Salmonid projects. The fact that the meter is portable, externally applied should allow for fast monitoring of water flows.

Specifications

Flow Range - 0 - 6 meters/second
Accuracy - + or - 5% (when used as directed)

Installation

The ultra/sonic meter can be moved around from pipe to pipe. The transducer face is simply coated with a light coating of silicone or modelling clay to prevent any air interface between it and the pipe to be metered. The transducer must be located 5-6 diameters from any elbows or turns that would affect the development of a full velocity profile. The ultra/sonic meter

requires full flow in the pipeline to be measured. The transducer should be on a vertical pipe or if on a horizontal pipe should not be located at the extreme top or bottom of the pipe, where either air bubbles or heavy solids could be located, thus affecting metering accuracy.

Comments

The Baird-Doppler ultra/sonic flowmeter requires 100 ppm of suspended particles, air bubbles of > or = to 30 microns in size to get a reading of flow rate in the pipeline being metered. Since the water used in the production of salmonids on Vancouver Island seldom exceeds 5 ppm (W.E. McLean), its application under these water conditions appears limited, if at all possible.

In a telephone conversation with Mr. Baird of Baird-Doppler manufacturers in Illinois, U.S.A. he said the following "the Baird-Doppler ultra/sonic flowmeter (Model UFT-503) is used by industry to measure contaminated flows, whereby the particle size and content requirements are satisfied, and that its application in salmonid rearing would be useless". Mr. Baird mentioned that this particular model (UFT-503) is outdated now and that their new ultra/sonic is capable of measuring water with suspended air bubbles or particles to the order of 25 ppm, 30 microns in size or greater. This still is above the 5 ppm encountered in the rivers or groundwater used by the South Coast projects.

In another conversation with Joe Latowski (instrumentation head of Crofton pulp and paper), he said "that with this type of ultra/sonic meter there is a possibility to inject air into the line upstream from the meter site. This will give a rough reading, but nothing that you would want to rely upon" (pers. commun.).

The only application that may satisfy the particle requirements may be in the measurement of hatchery effluent, if there is 100 ppm of > or = to 30 microns in size particles in the flow.

3.8 **Instrument - Annubar/Eagle Eye Flowmeters**
Sites - Conuma River, Puntledge River

Principles of Operation

Annubar is a primary flow sensor designed to produce a differential pressure that is proportional to flow. Annubar is comprised of four basic parts. There is the high pressure sensor with four impact ports facing upstream. Based on Chebychef calculus for averaging observations, the computer located ports sense the impact pressure caused by the flow velocity in each of the four equal cross-sectional areas of the flow stream.[17]

The interpolating tube inserted within the high pressure sensor transmits the continuous average of the impact (stagnation) pressure detected by the four sensing ports to the high pressure side of the differential pressure measuring device. The impact pressure is the sum of the pressure due to the velocity of the fluid and the line static pressure.[18]

The rear port pointing downstream senses the low pressure. The difference between the high pressure from the interpolating tube and low pressure from the rear port is proportional to the flow rate according to Bernoullis' Theorem. The resultant difference in the two pressures, high - low, equals the differential pressure which is transmitted to a secondary device such as a flowmeter, transmitter, recorder or controller.

The secondary device used by Fisheries is the Eagle Eye flowmeter which totalizes differential pressure in either linear to flow or differential pressure (MM H20).

General

An Annubar can be mounted horizontally or vertically on pipe runs. The diamond shaped sensor has been engineered to provide high accuracy. This design provides a uniform flow pattern around the sensor resulting in a very

accurate differential pressure as the flow passes around the Annubar, in front of the velocity sensor. This high pressure zone produces flow patterns which deflect particulates around the sensor. The diamond shaped sensor allows for a clog free design.

Specifications

Range - varies according to pipeline
Accuracy - + or - 1% of actual value

Installation

Annubar installation is relatively simple and quickly performed. The position for the primary sensor should be 10 pipe diameters from elbows or other points of turbulence. Once the sensor location is determined you weld on a coupling or bolt on a collar, attach nipples and a valve. The pipe is drilled through with standard pressurized drill equipment. The Annubar is then installed, valve opened and Annubar inserted. The secondary device such as the Eagle Eye flowmeter is then attached. The Eagle Eye can either be portable or permanently mounted.

Comments

Annubar/Eagle Eye systems are used extensively by the Pulp and Paper industry in a variety of conditions. Mr. J. Latowski, instrumentation head at Crofton Pulp and Paper said that "Annubar/Eagle Eye are one of the most reliable, inexpensive flow measuring devices on the market. They are used to measure liquid, steam, gas and have given years of reliable service. Maintenance time has been minimal with this system. Most of the sensor, eagle eyes used by Crofton are under $1,000 to purchase."

Annubar can be plugged into an alarm system, computer interface. Annubar is approved by the Underwriters Laboratory of Canada. The secondary device (Eagle Eye) can be used as a portable meter or mounted permanently. It

is probably best that it be mounted permanently because they are sensitive to rough handling. The differential pressure Eagle Eye can be used to take flow readings on different sizes of pipe and would be suited to portable use, though careful handling procedure should be observed.

Each system to be used in a particular situation is carefully studied after specifications have been sent to the Annubar/Eagle Eye representative. This assures proper sizing for flow ranges.

Eagle Eyes permanently mounted should be protected from any possible damage that may result from external objects, such as trucks backing up etc.

Due to the stationary fluid in the pressure line and meter, care must be exercised to prevent freezing and subsequent breakage.

3.9 Instrument - Bucket/Stop-watch

Site - All Projects

Principles of Operation

The simplest equipment for direct volume measurement consists of a bucket of known size, and a stop-watch (Figure 15). To use this technique flow in a pipe or open channel is allowed to stabilize, this usually takes only a few seconds after the water is allowed to flow into the system. The bucket is then placed underneath the outlet, and a stop-watch is started at the same moment. When the bucket is full, the watch is stopped. This gives the volume of flow for a known period of time and allows one to calculate the flow rate. The stop-watch and pail method can be used by almost anyone and is quite accurate. However accuracy depends on the size of the bucket and the relative rate of flow from the conduit. For example, if a 10 litre bucket is used and the flow rate is 200 litres/minute, the time to fill the bucket will be very short. Measurement of flow over a very short time is subject to inaccuracies because of human error involved in starting and stopping the watch. On the other hand, if the flow rate is small relative to the size of

the bucket, the time interval will be long. Thus the error due to human reaction time in starting and stopping the watch will be a very small portion of the total time employed in filling the bucket. This will reduce the error of the measuring technique.

4. OUTFLOW DEVICES, METHOD FOR MEASURING DISCHARGE BY VANCOUVER ISLAND SALMONID PROJECTS

4.1 Introduction

Water piped into a container will travel the course of that container and discharge through whatever outlet is inherent to that particular system. The most common method used by Fisheries to control water height and discharge is a stoplog weir structure.

Other methods used are bucket/stop-watch and Gurley meters. Weirs and Gurley meters will be discussed in the following sections on outflow devices.

4.2 Introduction to Weirs

Weirs are the simplest, least expensive devices that can be used to measure the flow of liquids in open channels. A weir can be defined as an obstruction built across an open channel over which the liquid flows, usually through an opening or notch. This then becomes the point of outflow or discharge. The edge or surface over which the liquid passes is termed the crest of the weir. The edge is generally cut with a sharp upstream corner so that the water tends to spring clear of the crest.[19]

Depending on the shape of the opening, weirs may be termed rectangular, trapezoidal, triangular (V notched) etc. as shown in Figure 16. In the case of rectangular or trapezoidal weirs the bottom edge of the opening is the crest and the side edges are called sides or weir ends. The sheet of water leaving the crest is called the nappe.[20]

Weirs used by the South Coast Unit fall into three categories. These are the 90° V notch, the rectangular suppressed and the rectangular contracted types. The following sections will focus on the standard requirements for standard tables and formulas to apply for accurate flow measurement. A critique of the existing weirs used by the South Coast Unit will be included.

4.3 Standard Conditions for Weirs

Weirs are acceptable measuring devices because for a weir of a specific size and shape with free flow steady state conditions and proper weir to pool relationships, only one depth of water can exist in the upstream pool for a given discharge. The discharge rates are determined by measuring the vertical distance from the crest of the overflow portion of the weir to the water surface in pool upstream from the crest and referring to computations or tables which apply to the size and shape of the weir.

For standard tables to apply, the weir must have a regular shape, definite dimensions and be set in a bulkhead and pool of adequate size so the system performs in a standard manner.

4.4 Weir Code

Twelve conditions must be met for a weir to be termed "standard". The criteria apply to V notch, rectangular contracted weirs. These conditions are:

1) The upstream face of the bulkhead should be smooth and in a vertical plane perpendicular to the axis of the channel.

2) The upstream face of the weir plate should be smooth, straight, and flush with the upstream face of the bulkhead.

3) The entire crest should be a level plane surface which forms a sharp, right angled edge where it intersects the upstream face.

The thickness of the crest, measured in the direction of the flow, should be between 1 to 2 mm. Both side edges of rectangular weirs should be truly vertical and of the same thickness as the crest.

4) The upstream corners of the notch must be sharp. They should be machined or filed perpendicular to the upstream face, free of mires or scratches, and not rounded off with abrasive paper or cloth. Knife edges should be avoided because they are difficult to maintain.

5) The downstream edges of the notch should be relieved by chamfering if the plate is thicker than the prescribed crest width. The chamfer should be at an angle of 45 degrees or more to the surface of the crest.

6) The distance of the crest from the bottom of the approach channel (weir pool) should preferably be not less than twice the depth of water above the crest and in no case less than .3 meters.

7) The distance from the sides of the weir to sides of the approach channel should preferably be no less than twice the depth of water above the crest and never less than .3 meters.

8) The overflow sheet (nappe) should touch only the upstream edges of the crest and sides.

9) Air should circulate freely both under and on the sides of the nappe.

10) The measurement of head on the weir should be taken as the difference in elevation between the crest and the water surface at a point upstream from the weir a distance of four times the maximum head on the crest.

11) The cross sectional area of the approach channel should be at least 8 times that of the overflow sheet at the crest for a distance upstream from 15 to 20 times the depth of the sheet.

12) If the weir pool is smaller than defined by the above criteria, the velocity of approach may be too high and the staff gauge reading too low. Corrections for velocity of approach may then have to be applied.[21]

4.5 Formulas Based on Standard Conditions

The formulas used by South Coast Unit personnel to measure flow over the three different types of weirs are based on the previous sections twelve criteria.

These formulas are in the imperial system of measurement and will be presented as such. These formulas are as follows:

1) Rectangular Contracted - Francis formula

$$Q = 33.33\ (L - 0.2H)H^{3/2}$$

where Q = discharge in cfs
L = length of weir in feet
H = head on the weir in feet

2) Rectangular Suppressed - Francis formula

$$Q = 3.33\ H^{3/2}$$

where Q = discharge in cfs
L = length of weir in feet
H = head on the weir in feet

3) 90° V notch - Cone formula

$$Q = 2.49\ H^{2.48}$$

where Q = discharge in cfs

H = head on the crest in feet

Prepared tables are available for each of these weirs, giving the discharge values for varying heads and lengths of weirs.

The next section will examine the weirs used by the Vancouver Island Salmonid Enhancement projects and determine if they are standard accurate flow measuring devices.

4.6 South Coast Unit Weir Types

As previously mentioned, three types of weirs are used on Vancouver Island. These are the rectangular suppressed, rectangular contracted and the 90° V notch weirs. Each of these three weirs will now be examined.

4.7 Rectangular Contracted Weirs

When the distance from the edge or sides of the weir notch to the sides of the weir pool are great enough to allow the water a free, unconstrained lateral approach to the crest, the water will flow uniformly and relatively slowly toward the weir ends. As the water from the sides of the channel nears the notch, it accelerates and turns to pass through the opening. This turning cannot occur instantaneously and a curved flow path or contraction results with water springing free to form a jet narrower than the weir opening.[22]

The rectangular contracted weir, as shown in Figures 17 and 18 is less common than the rectangular suppressed throughout the South Coast Unit. This weir type is non-standard, and to apply standard tables or formulas is to invite inaccurate flow measurement. Accurate discharge measurements from

nonstandard structures can be obtained only from specially prepared curves or tables based on calibration tests such as current meter ratings.

If we refer back to the twelve conditions required for standard tables or formulas to apply, this type of weir is non-standard in a number of ways. Firstly they are not sharp crested weirs. The standard weir is sharp crested, as shown in Figure 19. The sharp crested weir allows for the nappe to spring free, touching only the upstream edges of the crest and sides. In the fisheries weirs there is no sharp crest but rather a stoplog is often used which causes the nappe to cling. The clinging nappe allows for no aeration, further reducing accuracy of flow measurement.

The crest surface should be kept clean of debris and plant growth. The stoplogs are not always horizontal and water has been observed leaking between the stoplogs, which will provide additional errors in weir measurement.

It can be seen that this weir type is non-standard in the following means; clinging, non-aerated nappe and the fact that they are not sharp crested. A clinging nappe will produce drag on the flow slowing its velocity whereas a non-aerated nappe will produce an increased discharge due to the low pressure area beneath the nappe. Weir to pool dimensions will have to be checked in each instance, to see if the dimensions conform to the required standards.

This weir type in its current, non-standard form will have to be calibrated in place as a broadcrested weir or it will have to be modified to meet the requirements of a standard sharp crested weir. If the route of modification is taken, then standard tables and formulas would apply. Measurements derived from this weir in its present form are bound to be inaccurate and if possible a comparative measurement should be used before the measured flow over this device is trusted.

4.8 Rectangular Suppressed Weir

Rectangular suppressed weirs are the most common rectangular weir in use in the South Coast Unit.

A standard suppressed rectangular weir has its crest, consisting of a thin plate, so far removed from the bottom of the approved channel that full crest contraction is developed. The sides are consistent with the sides of the approach channel, therefore, no lateral contractions of water passing through the weir is possible.[23]

The same twelve criteria, as mentioned before apply, excepting those that pertain to side contractions. In the suppressed weir the sides of the approach channel should be consistent with the sides of the weir and should extend downstream beyond the crest to prevent lateral expansion of the nappe.

Figures 20 and 21 show two rectangular suppressed weirs found in the South Coast Units. This weir type is also non-standard because they are not sharp crested and have a clinging, non-aerated nappe. Pool to weir dimensions will have to be checked in each particular situation, for the rectangular suppressed weirs found on Vancouver Island projects are varied in shape and size. The rectangular contracted weirs also vary in shape, size and pool to weir dimensions will have to be checked in each specific situation.

Measurements derived from non-standard devices using standard tables will produce errors in the discharge values. A cross check system should be used to compare readings.

This weir type in its non-standard form could be calibrated as a broad crested weir, using a current meter to set up a discharge curve, or it could be modified to meet standard requirements. Calibration tests can be costly because ratings must be made at fairly close intervals over the full operating range, and the curves or tables prepared from the data.[24]

4.9 90° V Notch Weirs

The crest of the standard 90° V notch weir consists of a thin plate, the sides of the notch being inclined 45° from the vertical. The weir operates as a contracted weir and conditions for accuracy stated for the standard contracted rectangular weir apply.[25]

Figures 22, 23, 24 show some of the V notch weirs being used by the South Coast Unit. The 90° V notch is used mostly to measure discharge from burrows ponds. In this case the top stoplog has been modified to form a V notched weir, as shown in Figure 24.

The 90° V notch weirs are non-standard devices. They are not sharp crested and have clinging, non-aerated nappes. The V notched weirs are calibrated in gallons per minute, some imperial and others U.S. If these calibrations were based on standard formulas, they should be suspect as to their accuracy.

The other area of concern with the non-standard design is that of the minimum distance of the sides of the weir to the channel banks. The distance should be at least twice the head of the weir, and should be measured from the intersection point of the maximum water surface with the edges of the weir.[26]

The 90° V notch weirs found in use on the Vancouver Island Salmonid projects is the closest of all the weirs observed to being a standard device.

4.10 Selection of Weirs

In general when considering weirs, a rectangular suppressed weir or 90° V notch should be used for best accuracy. These two types are the most prevalent at the South Coast projects. With modification and calibration these weirs could be used with confidence.

Usually the range of flows to be measured by a weir can be fairly well estimated in advance. With this range in mind, the following points should be considered.

1) the minimum head should be at least 6.2 cm to prevent the nappe from clinging to the crest, and because at smaller depths it is difficult to get sufficiently accurate gauge readings to calculate reliable flow quantities.

2) the length of rectangular weirs should be at least 3 times the head.

3) the 90° V notch is the best type for measuring discharges less than .028 m^3/second. It is as accurate as the other types for flows from .028 m^3/second to .28 m^3/second. Thus it is well suited for discharges up to and a little beyond .28 m^3/second if sufficient head is available.

4) the crests, if possible, should be placed high enough so the water flowing over them will fall finely, leaving an airspace under and around the jets. If submergence is permitted, special computations and reduced flow measuring accuracy may be expected.[27]

4.11 Velocity of Approach in Weirs

An additional consideration in standardizing weirs is the velocity of approach to the weir. Weirs should be installed and maintained to make the velocity of approach negligible, but where this is impracticable, appropriate changes should be made. It should be borne in mind that moderate velocities of approach with low heads on the weir produce large errors, whereas comparatively high velocities of approach with larger heads on the weir produce relatively small errors.[28]

5.0 GURLEY METERS

5.1 Instrument - Gurley Meter # 622 Type AA

The Gurley #622 current meter as shown in Figure 26, consists of a bucket wheel inverted on a vertical axis which revolves when suspended in flowing water. Figure 25 shows the ancestral form of the modern day Gurley meter. A fine wire contacts the rotating shaft, and intermittently closes an electrical circuit, connected to an earphone. A small dry cell battery supplies power. The circuit is closed each revolution or each fifth revolution: separate binding posts permit selection of the count desired. The number of clicks sounded in the earphone is counted for a time varying from 40 to 20 seconds. From a rating table the velocity in meters per second may be read directly over to a range of 1 to 200 revolutions in 40 to 70 seconds, or .03 m/s to 3.38 m/s.[29]

When measuring lower velocities and the water is clear, the number of revolutions the bucket wheel makes can be counted by observing the wheel, and timing the revolutions.

Specifications

Operating range - .06 m/second to 7.0 m/second
Accuracy - + or - .5% over full operating range

5.2 Instrument - Gurley Meter # 665 (Figure 27)

Site - Puntledge River

Principles of Operation

The Gurley # 665 current meter consists of two main parts, the sensing unit and the indicating unit. This model differs from the 622 in that it is capable of indicating and recording water velocities directly. The 12.5 cm diameter bucket wheel revolves when suspended in the water and the revolutions

are transferred directly to an indicating unit which has four calibrated scales, two in ft/sec. ranging from 0 - 25 ft/sec. and two in meters/sec. ranging from 0 - 7 m/s. Water velocity is obtained directly in the absence of rating tables, chronometers or field note reduction.

Specification

Range - .06 m/s to 7.0 m/s

Accuracy - + or - 5% over the full range of the unit, 0.05% error caused by temperature change for each degree change from 75° F

* battery life of 80 hours or more

Comments

Gurley meters are proven and offer the only available practical means of measuring water velocities in open channels, rivers etc. They are reasonably inexpensive, serviced in British Columbia and will give many years of service if properly maintained.

Meters should be oiled frequently with a light machine oil during daily use as well as at the end of a days use. Gurley meters should be treated as fragile instruments, especially when being used around rocks, piers or other objects that may damage the meter.

The meter most widely used by Fisheries for the South Coast Unit is the 622. The range of this meter is from .06 m/s to 7.0 m/s. Many of the flows encountered in the various systems fall beneath the range of this model. For the majority of situations this model is not sensitive enough to measure flow.

Gurley manufactures another model as shown in Figure 28. This is the Pygmy type current meter #125 which has a range of .015 m/s to .91 m/s. The Pygmy meter is extremely sensitive to low velocities and can be used to measure flow of water in shallow streams, containers, flumes and canals where the depth of the water or the velocity is insufficient for using the larger

current meters. The construction of the Pygmy is similar to the 622 except for the smaller size and the use of a single contact, indicating only each revolution. The bucket wheel of the Pygmy current meter is .79 cm in diameter compared to the 1.97 cm diameter wheel of the 622.

The purchase of a Pygmy meter would allow for the measurement of low velocities, and cross checks for weirs, Annubar systems, bucket/stop-watch, etc. Used in combination with larger #622, the Pygmy could be used to measure points near the channel banks, walls where flows are often beneath the minimum threshold of the 622. This would provide a more accurate discharge rating.

5.3 Conclusion of the Existing Devices

This concludes the discussion of the existing devices used by the South Coast Unit to measure the flow of water through its various types of containers, channels. The following sections will deal with some available devices on the market, their applications etc., which may be considered for use in the future.

6.0 ALTERNATE DEVICES FOR MEASURING WATERFLOW

6.1 Parshall Flume

General Description

A Parshall flume is shown in Figure 28 in a specially shaped open channel flow section which may be installed in a canal, lateral or ditch to measure the rate of flow of water. The flume has three significant advantages:

1) it can operate with relatively small head loss

2) it has the capability of taking good measurements with no submergence, moderate submergence, or even with considerable submergence downstream, and

3) its velocity of flow is sufficiently high to virtually eliminate sediment deposition within the structure during operation.[30]

A distinct advantage of the Parshall Flume is its ability to function as a flowmeter over a wide operating range with minimum loss of head while requiring but a single head measurement for each discharge. The head loss is only about one-fourth of that needed to operate a weir having the same crest length. Another advantage is that the velocity of approach is automatically controlled if the correct size of flume is chosen.

The main disadvantages of Parshall flumes are:

1) they cannot be used in close coupled combination structures consisting of turnout, control, and measuring device,

2) they are usually more expensive than weirs or submerged orifices,

3) they require a solid watertight foundation,

4) they require accurate workmanship for satisfactory construction and performance.[31]

Parshall flumes are designated by the throat width, W, and dimensions are available for flumes from the 2.54 cm size for discharges as small as 17 lpm to 15.2 meter size for discharges as large as 85 m^3/second. The flumes may be built of wood, concrete, galvanized sheet metal, or other desired materials. Large flumes are usually constructed on the site, but smaller flumes may be purchased as prefabricated structures to be installed as one piece.

Figure 30 shows a Parshall flume equipped with standard end adaptors for installation in a pipeline. Use of Parshall flumes in hatcheries is a possibility and their application should be looked into.

6.2 Orifice Plate

General Description

An orifice plate used as a measuring device is a well defined, sharp edged opening in a wall or bulkhead through which flow may occur. For true orifice flow to occur, the water surface upstream from the orifice must always be well above the top of the opening. If the upstream water surface drops below the top of the opening, the flow ceases to follow the laws of orifice discharge and the opening performs as a weir. Usually the orifice should have a specific and standard size and shape, and a means of measuring the head acting upon it.[32]

Free and submerged orifices may be either contracted or suppressed. In a contracted orifice, the perimeter or the opening is so far removed from the walls of the approach channel, or from other surfaces of a disturbing nature, that the filaments of water fully contract to form the vena contracta after they pass through the orifice. A suppressed orifice is one whose perimeter partly or fully coincides with the grates of the approach channel or with other surfaces that would eliminate or reduce contraction.[33]

Where there is sufficient fall to measure water with a weir, the weir should normally be chosen. Not only is the weir less susceptible to interference from weeds and trash, but such clogging is easily visible. Also, the weir is usually the least expensive type of measuring structure. When the amount of fall is not adequate for a weir, the Parshall Flume or the submerged orifice may be used. A disadvantage of the submerged orifice is that accumulations of submerged debris or of sand and sediment upstream from the orifice may prevent accurate measurement.

6.3 Venturi Meters

There are a number of ways to measure flow in pipelines and one of these is the Venturi meter.

Venturi meters are perhaps the most accurate type of flow measuring device that can be used in a water supply system. They contain no moving parts, require very little maintenance and cause very little head loss. Venturi meters operate upon the principle that flow in a given closed conduct system moves more rapidly through areas of small cross section (D_2) than through areas of large section (D_1), as shown in Figure 31. The total energy in the flow, consisting primarily of velocity head and pressure head is essentially the same at the small (D_1) and large (D_2) areas of cross section. Thus the pressure must decrease in the constricted throat (D_2), where the velocity is higher; and conversely the pressure must increase at (D_1), upstream from the throat, where the velocity is lower. This reduction in pressure from the meter entrance to the meter throat is directly related to the rate of flow passing through the meter, and is the measurement used to determine flow rate. Tables or diagrams of this head differential versus rate of flow may be prepared, and flow indicators or recorders may be used to display the differential or the rate of the flow.

The relationship of rate of flow, or discharge, to the head and dimensions of the meter is:

$$Q = \frac{CA_2\sqrt{2gh}}{\sqrt{1 - r^4}}$$

Where:

A_2 = cross sectional area of the throat in square feet

h = difference in pressure head between upstream pressure measuring section and the downstream pressure measuring section in feet

g = 32.2 feet per second (gravity)

r = ratio of the throat diameter to the pipe diameter = D_2/D_1

C = coefficient of discharge for the Venturi meter[34]

The coefficient of discharge for the venturi meter will range from an approximate value of 0.935 for small throat velocities and diameters, to 0.988 for relatively large throat velocities and diameters.[35]

Many variations of Venturi meters exist, each of which is tailored to meet the requirements for specific installations. Venturi meters tend to be expensive and require full pipelines for proper operation.

6.4 Calibration of Pumps, Gates, Valves

The calibration of pumps, valves may be made in the field using an approved flow measuring method. Properly prepared curves are a reliable means for obtaining accurate discharge measurements. In the case of turbines or pumps, discharge versus power relationships are generally desired. They may be determined by measuring the average output or input during the period which discharge measurements are made for various load conditions. Suitable curves or tables may be developed from this test data to show the rate of flow, Q, that occurs for specific types of operation. Curves may also be prepared from model test data. Due care must be taken to account for any changes in the efficiency of the machines due to long service or other deteriorating factors.[36]

For gates and valves, discharge versus gate opening curves for various appropriate heads are desired. These may be determined by measuring the rates of flow at given rate or valve openings under specific head conditions. By operating over the full range of openings and heads, data may be obtained for establishing the formulas of curves. Generally the curves would show the rates of flow in m^3/second that occur through the gate or valve at specific openings, expressed in percent of full open, for the pertinent operating heads. These curves may also be prepared from model test data.[37]

6.5 Trajectory Methods

Trajectory methods consist of measuring the horizontal and vertical co-ordinates of a point in the jet issuing from the end of a pipe. The pipe may be either vertical or horizontal. The principal difficulty with this method is in measuring the co-ordinates of the flowing stream accurately.

For vertical pipes, Lawrence and Braunworth determined that when the height of the jet exceeded 1.4 D^1, as determined by sighting over the jet to obtain the maximum rise, the flow is given by the formula:

$$q = 5.01\ (D^1)^{1.99}\ (H^1)^{0.53}$$

where q = rate of flow in gallons per minute (US)
D^1 = inside diameter of the pipe in inches and
H^1 = height of jet in inches

When the height of the jet is less than 0.37 D, the flow is similar to that over a weir and is given by the formula:

$$q = 6.17\ (D^1)^{1.25}\ (H^1)^{1.35}$$

For jet heights between 0.37 D^1 and 1.4 D^1, the flow is somewhat less than given by either of these equations.[38]

In horizontal pipes either the California pipe method or the Purdue method may be used. The California pipe method applies only to partially filled horizontal pipes whereas the more general Purdue method applies equally well to both partially and completely filled pipes. Because of its more general application and convenient usage, the Purdue method is recommended. The Purdue method consists of measuring the co-ordinates of the upper surface of the jet as shown in Figure 32. If the pipe is flowing with a depth less than 0.8 D at the outlet, the vertical distance Y can be measured at the end of the pipe where X = 0. For higher rates of flow, Y may be measured at horizontal distances X from the pipe exit of 6, 12, or 18 inches.[39]

The most accurate results will be obtained when the pipe is truly horizontal. If it slopes upward the indicated discharge will be too high. If it slopes downward the indicated discharge will be too low. Difficulty will also be experienced in making the vertical measurement Y because the top of the jet will usually not be smooth and well defined.[40]

6.6 Specialized Methods

The previous six sections have listed a few of the more common methods of measuring waterflow, either in open channel or pipeline. There are many devices available, however many of these have specialized applications and requirements. A list of these methods will be included here, but, a detailed description may be obtained through Mr. W.E. McLean, support biologist for the South Coast Unit. Mr. McLean will have the manufacturers bulletins and other material which went into this report.

These methods will be listed under the headings of either open channel (1) or pipeline devices (2).

1. OPEN CHANNEL DEVICES

1) Measurement by Floats - surface velocities

2) The Pitot Tube - consists of a tube with a right angle bend which, when partly immersed with the bent part under water and pointed directly into the flow, indicates velocity of the flow by the distance that water rises in the vertical stem.

3) Salt Velocity Method - based on the fact that salt in solution increases the electrical conductivity of water. Electrodes measure the time required for the salt solution to pass from the upstream to downstream electrodes.

4) Salt Dilution Method - consists of adding a concentrated salt solution of known strength to the channel and by chemical analysis determining its dilution after it has flowed far enough to mix completely with the channel.

5) Color - Velocity Method - consists of determining the velocity of a slug of dye between two stations in the channel. The velocity multiplied by the cross sectional area of the channel gives the discharge.

6) Color - Dilution Method - consists of injecting a known concentration of a suitable dye into the stream and measuring its concentration after it has travelled far enough to mix thoroughly with the stream.

7) Radioisotope Method - this is a variation of the dilution method, using a radioactive material as the tracer substance. The dilution of the radioactive substance is measured by Geiger or scintillation counters.

8) Acoustic Flowmeters - operates on the principle that the difference in time of arrival of two simultaneously created acoustic or sound pulses travelling in opposite directions through the water can be related to velocity of flow.

9) Slope - Area Method - consists of using the slope of the water surface, in a uniform reach of channel, and the average cross sectional area of that reach, to give a rate of discharge. The discharge may be computed from the Manning formula:

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

where Q = discharge in cfs

A = mean area of the channel cross section of the channel in square feet

R = mean hydraulic radius of the channel in feet

S = slope of the water surface = $\frac{\text{fall}}{\text{length of course}}$

n = a roughness factor depending on the channel lining which can vary from 0.010 to 0.06

10) Deflection Meters - deflection meters consist of a wand or vane that projects into the flowing fluid, and a sensing element that measures the deflection caused by the force of the flow against the vane.

11) Weir Sticks - are commercial calibrated stick or staff gauge type devices which may be placed by hand upon the crest of a weir and readings taken at the top of the roll-up of water to indicate the rate of flow. Weir sticks, at best can only approximate the actual flow.

12) Stevens Flowmeters - these meters are used in conjunction with primary devices such as weirs or flumes. A change in float level is transferred through a set of flow range gears to a cam whose shape is selected to match the characteristics of the type of weir or flume used. The cam converts the change in level, or head, to an analog motion proportional to flow and moves the pointer, or pen, to indicate the new flow value.

13) Ultra/sonic Flowmeters by (Sirco) - this is not a Doppler ultra/sonic meter, but rather is used to measure flow in open channels. This meter may be the answer to establishing calibrated weirs in the South Coast Unit. The Doppler meter as previously described in section 3.7 measures flow in pipelines. The Sirco ultra/sonic meter is apparently the finest, most accurate and reliable ultra/

sonic flow monitor available for measuring flow in open channels. A high frequency pulse carried over a coaxial cable to the transmitter, located in the transceiver, converts the pulse into an aduio emission which, aimed at the level of surface, i.e.; water, bounces back to the receiver where it is converted into an electrical impulse. The measured time difference, a level dependant variable, is then integrated in the Level/Flow logic module with the characteristic of the flume, weir etc. The level and volume of flow is then displayed and/or recorded.[41] Figure 33 shows the relationship of the meter to the open channel being measured.

2. PIPELINE DEVICES

1) Flow Nozzles - operates on same basic principles as Venturi meters. The flow nozzle is a venturi meter that has been simplified and shortened.

2) Pitot Tubes - may be used to measure flow in pipelines as well as open channels. Annubar/Eagle Eye systems are a type of Pitot Tube. Apparently at low velocities, head differentials are small and reading errors greatly affect the results.

3) Salt Velocity Method - this method remains the same for closed conduits, as in open channels, but the salt injecting system and the sensing electrodes become more complex.

4) Color Velocity - consists of measuring discharges in pipelines by determining the velocity of a slug of dye between two stations in the pipe.

5) Radioisotope Methods - consists of injecting radioisotopes into the pipeline and measuring the dilution. Special equipment is required here and often large quantities of isotope must be used.

6) Micro Motion Model C Mass Flowmeters - this is a mass flowmeter that monitors the motion of each molecule of flowing material and sums all of the flow forces to generate a total force that is an accurate, linear measurement of mass flows. The meter uses electro-optical techniques to sense the forces. The principles of Coriolis force or gyroscopic procession are utilized by the Model C Mass Flowmeter to measure flow.

7.0 FIELD WORK

During the survey of methods used to measure water flow in the South Coast Unit, some field measurement was performed using the Gurley #622 AA meter. The purpose of this measurement was to provide comparative measurements to existing devices. Field work was done at three sites, and those will be discussed in the following sections.

7.1 Puntledge River

Coho Raceways, Lower Site

At Puntledge the object of the field work was to compare the Gurley meter readings to that of the Annubar/Eagle Eye and the rectangular weir.

The Annubar/Eagle Eye measure inflowing water and the only means of checking their accuracy has been a non-standard rectangular weir (See Figure 34). A series of measurements were done on this weir that did not correspond to that of the Eagle Eye.

The Gurley metering was an attempt to provide a third device which would allow for comparison of the three methods. The velocities of flow in the coho raceways proved to be beneath the sensitivity of both the Gurley #622 AA and Gurley #665 direct reading unit. Further, the particular Gurley meter used was later found after servicing by Goertz Scientific Instruments in Vancouver,

to contain an oversized part which increased the minimum velocities (threshold) necessary to operate the meter.

Due to the insensitivity of the meter, no statistical comparison could be established. One of the conclusions reached was that, as previously described the purchase of a Pygmy Gurley meter would allow for these comparisons to be done. The Annubar/Eagle Eye system which are going to be used quite extensively by Fisheries on the South Coast Unit should be comparatively rated at some point in the future.

7.2 Conuma River

East Earth Channel

At Conuma River two sources of water are piped into these earthen channels. Ground water and Leagh creek water are used independently or in combination depending on temperature, quantity available etc. Ground water is pumped whereas Leagh creek is gravity fed.

During my visit to Conuma, only one earth channel was operative. Flow into this channel is monitored by Annubar/Eagle Eye, registering inflow in lpm.

The problem encountered was a tremendous amount of leakage in these channels. By measuring the velocities with the Gurley meter, comparing it to the Annubar/Eagle Eye and outflow weir it was hoped than an understanding of the leakage would result.

At the time of the field work the Eagle Eye read 2650 lpm flowing into the channel. The amount of water leaving the outflow weir (through the stoplogs, the top stoplog was higher than the water depth) was 60 lpm. An additional 9 lpm was measured as it flowed into the neighboring channel. A total of 2581 lpm are unaccounted for. If water is being pumped under these

conditions, it is very demanding of the pump system. In times of water shortage this could prove to be inefficient, to say the least.

Weir measurements under these conditions proved to be worthless. The Gurley metering was to determine the velocities in the channel. The channel is 95 meters long by 6.0 meters wide. Water flows into a culvert and upwells vertically into the channel. The Gurley meter was capable of measuring velocities 6.0 meters down the channel from the culvert location. A centerline velocity check was run the length of the channel to see how the flow pattern tapered. The Gurley #622 AA proved only able to register velocity in the first 6.0 meters of the channel.

The float method was used to see if there was any flow at all, and in some cases the float moved back towards the point of inflow, this could have been due to the uneven nature of the channel bottom.

This channel is divided into three sections for fish husbandry purposes. In using the Gurley meter and float method of measuring velocities it seems apparent that the water is being lost in the first section from the inflow, and most of it in the first 6.0 meters. The water may be percolating vertically downward to some aquifer or pocket.

The bottom of the first section in this channel could be lined with some material such as bitumen emulsions which are on the market. This would determine if the leakage is in the first section.

This channel may operate more efficiently with the other channels full, but to use it independently is a tremendous waste of water.

Under these conditions it is very difficult to establish a statistical comparison between the Annubar/Eagle Eye, weir, Gurley meter devices.

7.3 Robertson Creek

Earth Channel 1A

Measurements were taken at Robertson Creek in channel 1A using the Gurley Meter. Figure 35 shows the outflow weir (rectangular suppressed in this photo) that is used to measure water flowing through the channel. At the time of the field work there were no fish in these channels. During the fish rearing period these rectangular weirs are stopped up and water flows down through a screen, then up and out through plywood boxes which are located on the sides of these weirs (as shown in Figure 33). What this means is that during the rearing period these channels are stopped up to prevent fish escape and by doing this there is no weir crest to measure the flow of water through the channel. At the opposite end of the channel where water enters, there are two metal staff gauges that are used as flow indicators during fish rearing periods. Measurements on the weir crest have been taken during the non-rearing season and a corresponding staff gauge readings are used to set up a relationship of discharge to water height.

The problem here is that measurement on this weir, in its current non-standard form, along with channel leakage would provide inaccurate flow information.

A current meter station was established in earth channel 1A and a number of measurements were taken. The level of water in the channel was raised to cover the operating range and the discharges determined. The velocities in the channel were close to the minimum range of the Gurley meter, but differences between the weir and the Gurley were significant. These can be tabled as follows:

Staff Gauge (ft)	Gurley Reading	Weir Reading
.9	.22 m^3/s	.24 m^3/s
1.2	.37 m^3/s	.30 m^3/s
1.3	.43 m^3/s	.32 m^3/s

The velocities in the channel were close to the minimum threshold of the Gurley. The use of a Pygmy meter to establish a discharge curve is what is required. The velocities in the channel would be beyond the minimum threshold of the Pygmy meter and an accurate curve could then be developed.

8.0 Conclusions

The contents of this report point out that an accurate measurement of waterflow in many instances is still in the pioneer stages. In the past, methods such as eyeballing waterflows may have been acceptable, but with modern technology, this is no longer justifiable. With the high loading rates in common use, accurate water flow measurements are essential for efficient hatchery operation.

The existing weirs should be standardized, or calibrated as non-standard devices to establish measuring accuracy. Depending on the individual weir, the decision as to whether to calibrate as a non-standard device, or to modify to a standard form will depend on the situational aspects. In some instances it may be desirable to modify into a standard weir. Critical flow measurements taken on non-standard, non-calibrated weirs should be cross checked where possible, by some other method of measurement.

The future construction of cement channel, earthen channels etc. should take into account the need for a flow measuring device. This could be included at the blueprint stage and structures such as weirs, Parshall flumes, orifice plates could be designed into the proposed system. This would prevent the problem of standardizing or calibrating flow measuring structures after the construction of rearing containers.

Efforts should be made to switch over to the metric system to avoid confusion and errors that can result in using a number of different units to measure waterflow.

TABLE 1

Big Qualicum
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Chinook Rearing Channel (1)	13,600 lmp to 17,000 lpm	?	Gurley Meter
Coho Rearing Channel (1)	10,200 lpm to 23,796 lpm	?	Gurley Meter
Concrete Rearing Channels (2)	3,400 lpm to 23,800 lpm	?	?
Rearing Tubs (6)	50 lpm to 230 lpm	Bucket/ Stop-watch	
Burrows Ponds (6)	450 lpm to 2,940 lpm		90° "V" Notch Weir
Steelhead Troughs (6)	30 lpm per trough	Bucket/ Stop-watch	
Pumphouse			
3 pumps @	6,436 lpm	Foxberg Diff.	
2 pumps @	4,826 lpm	Pressure	
1 pump @	3,028 lpm	Meters	
Spawning Channel			
Incubation Flow	119,000 lpm	Gurley	
Spawning Flow	153,000 lpm	Meter	
Incubation			
Heath Trays (1110) (500 to be built)	4 lpm to 20 lpm (12 lpm average)	Bucket/ Stop-watch	
Free Style (8)	20 lpm to 60 lpm	Bucket/ Stop-watch	

TABLE 2

Little Qualicum
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Spawning Channel			
Spawning Flows	51,000 lpm to 76,500 lpm	Gurley Meter	?
Incubation Flows	51,000 lpm to 76,500 lpm	Gurley Meter	?
Chinook Rearing Channels (3)	8,500 lpm to 25,500 lpm	Rectangular Weir	Rectangular Weir

TABLE 3

Puntledge River
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Lower Site			
Concrete Raceways (2)	5,100 lpm to 17,000 lpm	Annubar/ Eagle Eye	Rectangular Weir (suppressed)
Chum Rearing Ponds (2)	900 lpm to 2,700 lpm	?	Rectangular Weir (contracted)
Keeper Channels (4)	320 lpm to 2,700 lpm	Bucket Stop-watch	
Intermediate (32) Troughs	50 lpm to 230 lpm	Bucket/ Stop-watch	
Aeration Tower	51,000 lpm	Sparling Series 500 Flowmeter	
Incubation			
Heath Stacks (1440)	4 lpm to 20 lpm	Bucket/ Stop-watch	
Free style (8)	20 lpm to 60 lpm	Bucket/ Stop-watch	
Aitken Cells (64)	30 - 35 lpm		

TABLE 4

Puntledge River
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Upper Site			
Semi natural Channel (1)	34,000 lpm to 51,000 lpm	Rectangular Weir (suppressed)	Gurley Meter
Spawning Channel (1)	51,000 lpm to 119,000 lpm	Pump Capacities	Gurley Meter
Intermediate Troughs (12)	50 lpm to 230 lpm	Bucket/ Stop-watch	
Burrows Ponds	450 lpm to 2,950 lpm		90° "V" Notch Weir
Rearing Tubs	50 lpm 230 lpm	Bucket/ Stop-watch	

TABLE 5

Quinsam River
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Intermediate Troughs (26)	50 lpm to 230 lpm	Bucket/ Stop-watch	Bucket/ Stop-watch
Burrows Ponds (18)	450 lpm to 2,940 lpm	?	90° "V" Notch Weir
Round Tubs (10)	50 lpm to 230 lpm	Bucket/ Stop-watch	?
Incubation			
Heath Trays (2860)	4 lpm to 20 lpm	Fisher/Porter Impact Tubes	
Free Style (8)	20 lpm to 60 lpm	Bucket/ Stop-watch	
Aeration Tower and Attraction Channel Water (from clarifier)		Fisher/Porter Magnetic Meter	
Pump Water from Quinsam River to Filter		Fisher/Porter Magnetic Meter	
Quinsam River Water From Filter to Aeration Tower		Fisher/Porter Magnetic Meter	
Monitors Domestic Effluent			Fisher/Porter Magnetic Meter

TABLE 6

Conuma River
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Earthen Channels (3)	1,800 lpm to 5,000 lpm		Annubar/ Eagle Eye
Keeper Channels	320 lpm to 2,700 lpm	Bucket/ Stop-watch	
Intermediate Troughs	50 lpm to 230 lpm	Bucket/ Stop-watch	
Raceways (4)			
Incubation			
Heath Trays	4 lpm to 20 lpm	Bucket/ Stop-watch	

TABLE 7

Nitinat River
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Intermediate Troughs (20)	50 lpm to 230 lpm	Bucket/ Stop-watch	
Keeper (40) Channels	320 lpm to 2,700 lpm	Bucket/ Stop-watch	
Chum Rearing (8) Ponds	1,700 lpm		
Combination Channels (4)	1,700 lpm		
Incubation			
Heath Trays (304)	4 lpm to 20 lpm	Bucket/ Stop-watch	
Aitken Cells (192)	30 lpm to 35 lpm		
Aeration Tower	2,000 lpm to 6,000 lpm	Sparling Meter #185	
Groundwater Pumps	360 lpm to 5,400 lpm	Sparling Meter #103	

TABLE 8

Robertson Creek
Areas, Flow, and Measurement Methods

Structure or Container Type	Operating Range	System of Measurement Inflow	Outflow
Round Tubs (9)	50 lpm to 230 lpm	Bucket/ Stop-watch	
Intermediate Troughs (17)	50 lpm to 230 lpm	Bucket/ Stop-watch	Bucket/ Stop-watch
Earthen Channels 5B + 6B (2)	45,900 lpm thru each	?	Rectangular Weir
Keeper Channels (6)	320 lpm to 2,700 lpm	Bucket/ Stop-watch	
Raceway (2) 1B + 2B	8,500 lpm to 17,000 lpm	Rectangular Weir (suppressed)	
Steelhead Raceways A-F (6)	1,700 lpm to 3,400 lpm for each raceway	Notched Value (Rough)	
Chinook Rearing & Adult Holding Channel (4)	12,750 lpm for each channel		Rectangular Weirs
Test Flume	17,000 lpm		
Earthen Channels 1A-1VA (4)	17,000 lpm to 25,500 lpm	Rectangular Weir	Rectangular Weir
Incubation			
Heath Trays (1280)	4 lpm to 20 lpm	Pako Sho-Flo	Bucket/ Stop-watch

10.0 REFERENCES

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2) Fischer & Porter, Instruction Manual, 10D1430 A-1

3) Wheaton, F.W., Aquacultural Engineering, John Wiley & Son, U.S.A., 1977

4) Fischer & Porter, Instruction Manual, 10D1430 A-1

5) Ibid. to 4

6) Ibid. to 4

7) Fisher & Porter, Instruction Bulletin, 10F1030 (Revision 2)

8) Wheaton, F.W., Aquacultural Engineering, John Wiley & Sons, U.S.A., 1977

9) Ibid. to 8

10) Sparling Instruction Manual Ids. 500/501A

11) Ibid. to 10

12) Sparling Product Data Sheet DDS - 105

13) Ibid. to 12

14) United States Department of the Interior, Water Measurement Manual, 2nd Edition, Denver Colorado, 1967 pg. 178

15) Ibid. to 14, p. 181

16) Ibid. to 8, p. 331

17) Annubar Flow Measurement Manual

18) Ibid. to 17

19) Leupold & Stevens, Stevens Water Resources Data Book, 3rd Edition, Oregon, U.S.A., 1978

20) Ibid. to 14, pg. 7

21) Ibid. to 14, pgs. 12, 13

22) Ibid. to 14, pg. 9

23) Ibid. to 14, pgs. 13, 14

24) Ibid. to 14, pg. 5

25) Ibid. to 14, pg. 15

26) Ibid. to 14, pg. 15

27) Ibid. to 14, pg. 17

28) Ibid. to 14, pg. 25

29) Teledyne Gurley, Hydrological Instruments, Bulletin 700

30) Ibid. to 14, pg. 43

31) Ibid. to 14, pg. 44, 45

32) Ibid. to 14, pg. 89

33) Ibid. to 14, pg. 89

34) Ibid. to 14, pg. 185, 186

35) Ibid. to 14, pg. 185, 186

36) Ibid. to 14, pg. 203, 204

37) Ibid. to 14, pg. 204, 205

38) Ibid. to 14, pg. 199, 200

39) Ibid. to 14, pg. 199, 200

40) Ibid. to 14, pg. 199, 200

41) Sirco, Ultra - sonic flow velocity monitor for pressurized pipes, series F40

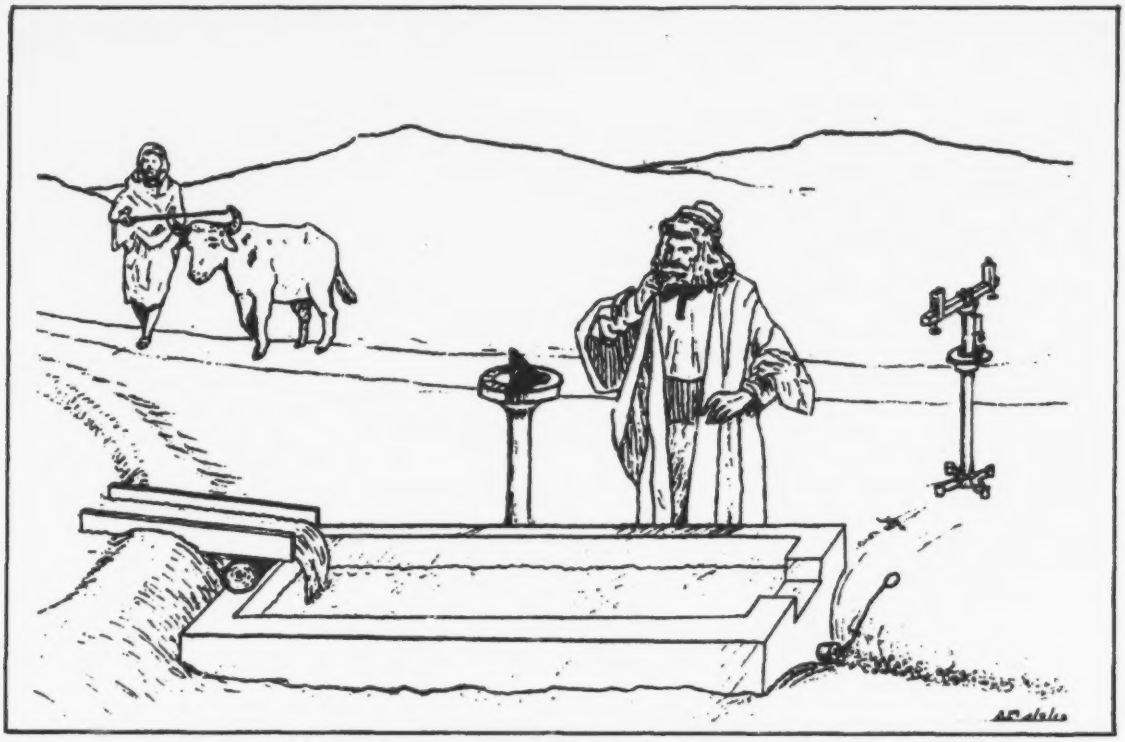


Figure 1. Hero of Alexandria performing the worlds first valid streamflow measurement, first century A.D. (Water Current Meters, Frazier, 1974)

Figure 2. Leonardo conducting experiments on the velocity-distribution in streams. (Water Current Meters, A.H. Frazier, 1974)

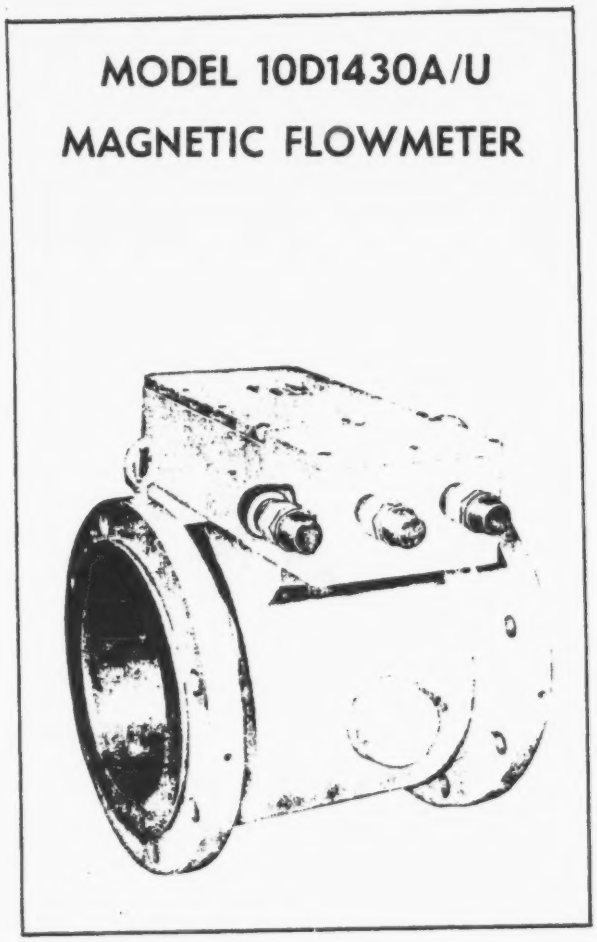


Figure 3. Fischer & Porter Magnetic Flow Meter (Instruction 10D1430 A/U, Fischer & Porter)

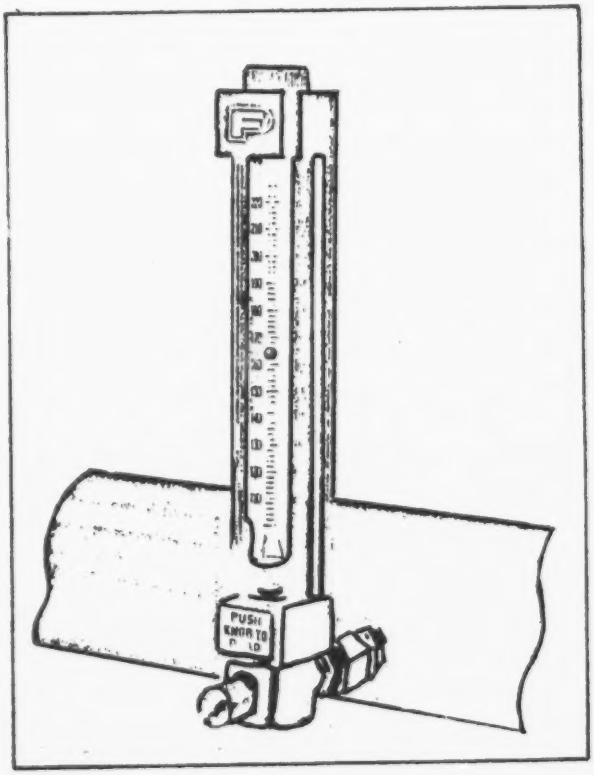


Figure 4. Series 10F1030 Fischer & Porter Impact Tube. (Fischer & Porter Instruction Bulletin 10F1030 revision 2)

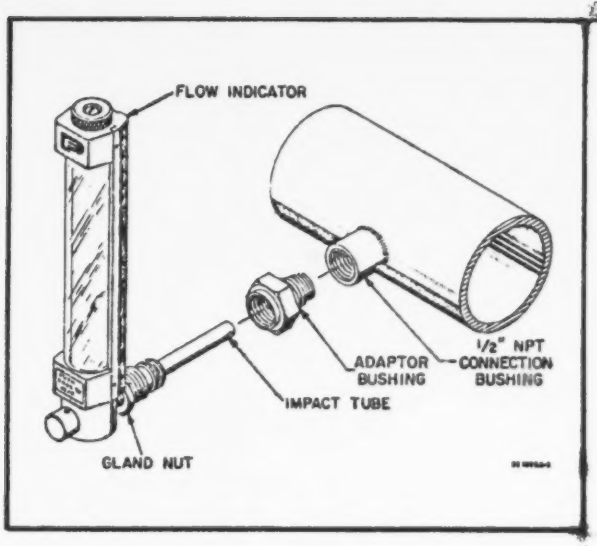


Figure 5.

Installation procedure for a Fischer & Porter Impact Flow Meter (Fischer & Porter Instruction Bulletin 10F1030 revision 2)

Figure 6.

Pako Sho-Flo Indicator (Rotameter) in use at Robertson Creek, to measure incubation flows.

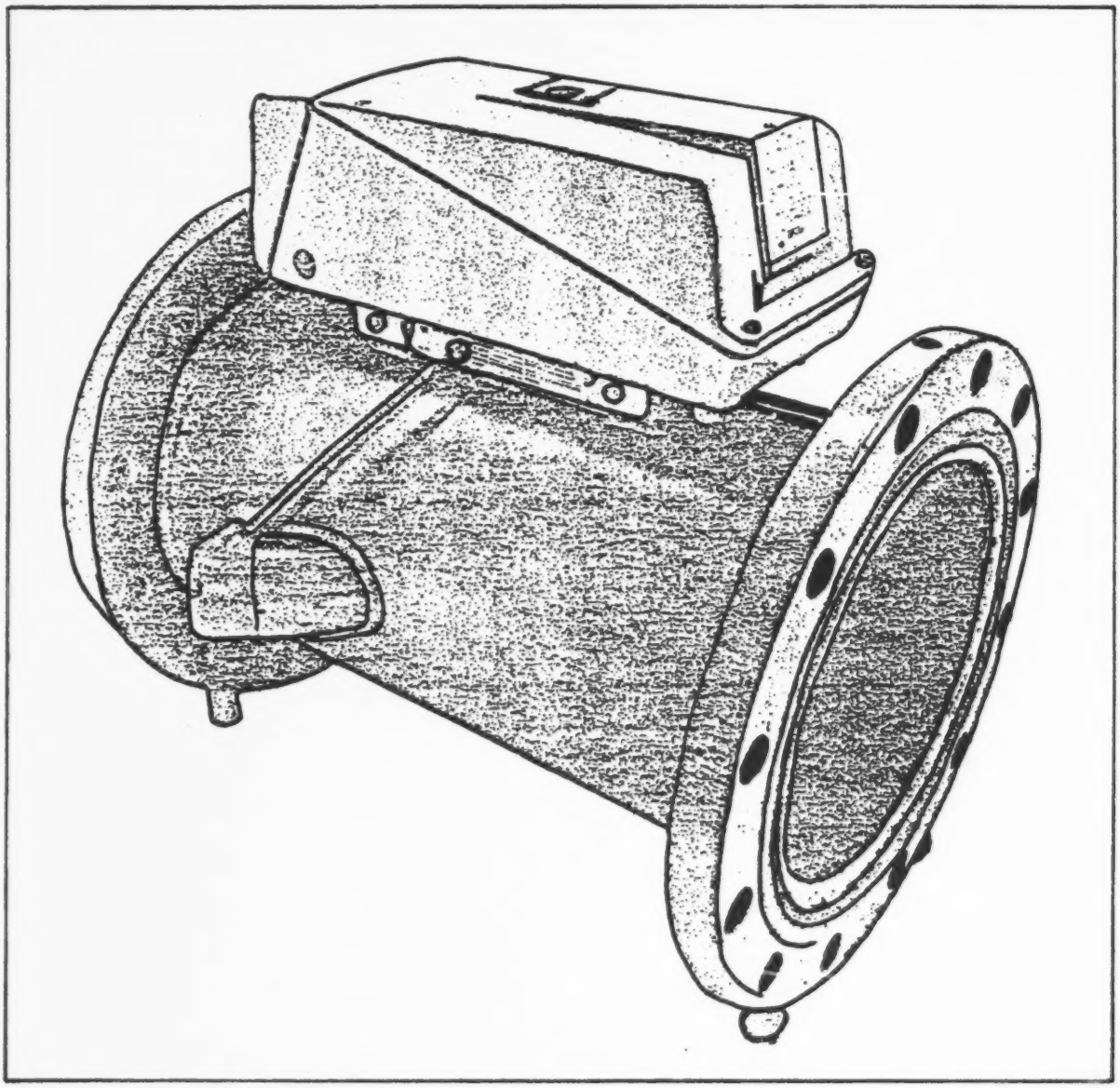
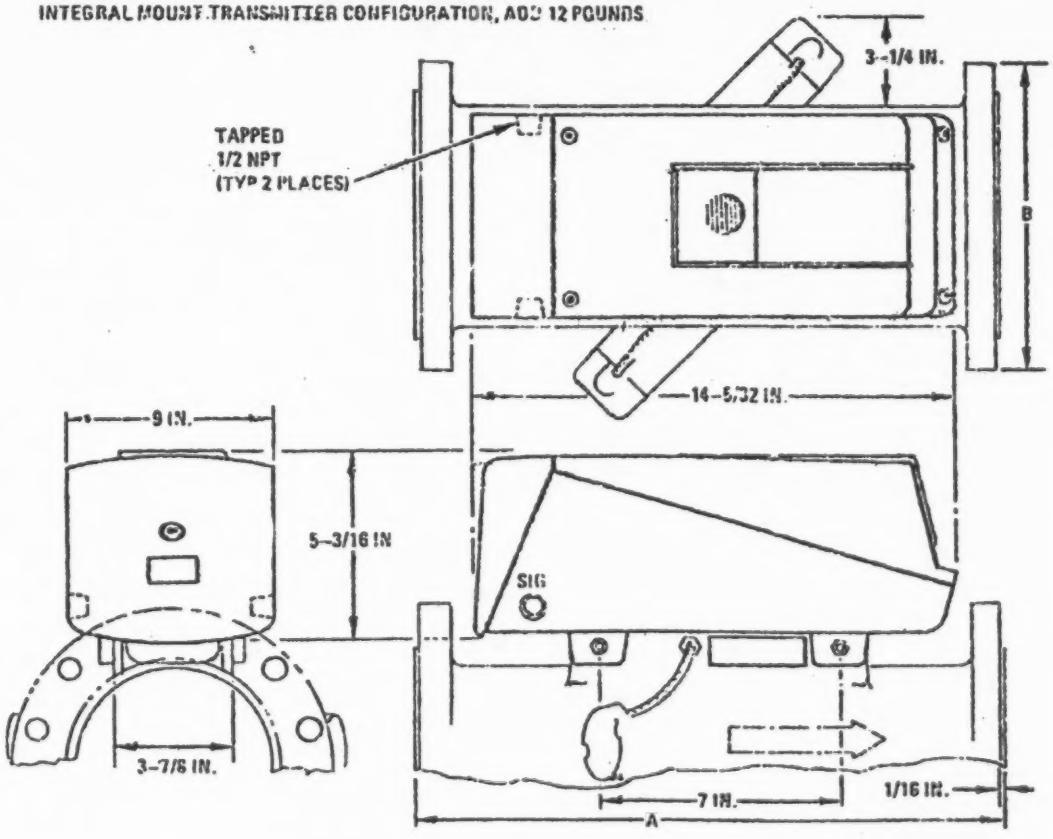


Figure 7. Sparling Series 500 Flow Meter (Instruction Manual 500/501 A)

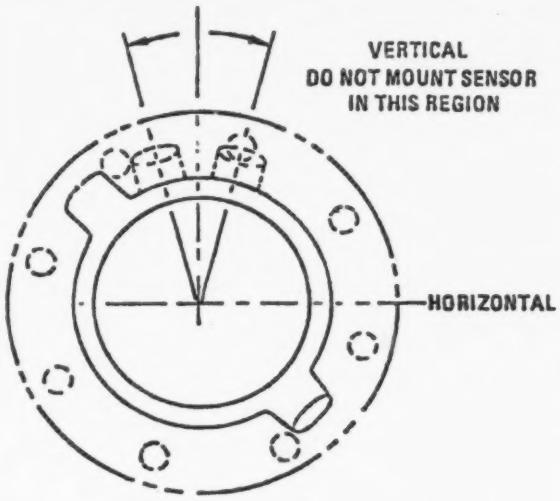
SIZE	"A" FLANGED TUBES VICTAULICS	"A" PLAIN ENDS	"B" FLANGED	"B" VICTAULIC PLAIN	NOMINAL SHIPPING WEIGHT	
					FLANGED	VICTAULIC PLAIN
4	20	26	9	4.5	65	40
6	20	26	11	6.6	80	45
8	20	28	13.5	8.6	120	65
10	20	28	16	10.8	155	80
12	25	28	19	12.8	245	125
14	25	28	21	14	245	140
16	25	30	23.5	16	290	170
18	25	30	25	18	890	195
20	30	30	27.5	20	500	215
24	30	30	32	24	590	255

150 LB ANSI RF END CONNECTION SENSOR W/O TRANSMITTER. FOR INTEGRAL MOUNT TRANSMITTER CONFIGURATION, ADD 12 POUNDS



Series 500 Flowmeter System -- Integral-Mount Configuration

Figure 8. Series 500 Flowmeter system. (Instruction Manual IDS 500/501 A)



Transducer Mounting Constraints

ter for connection of system power (PWR). Removal of the electrical section cover will permit access to the screw type power connect terminals (see Figure 3-3). The terminals will accept No. 8 spade lugs.

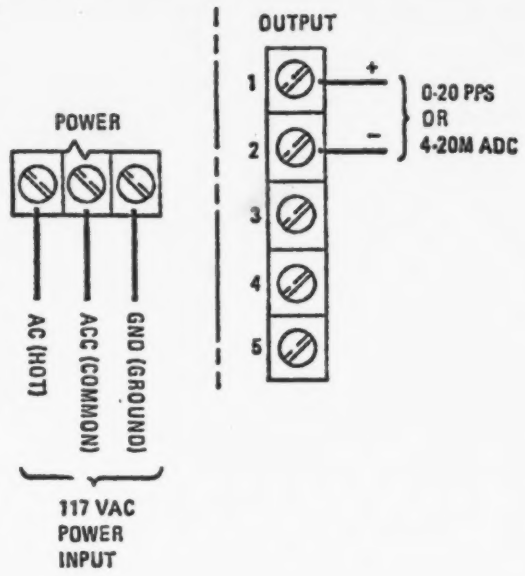
(2) Output – A tapped ½" NPT hole (see Figure 3-1) is provided in the Transmitter for connection of output (SIG) leads. Removal of the electrical section cover will permit access to the screw-type signal-connect terminals (see Figure 3-3). The terminals will accept No. 8 spade lugs. Signal connections are made as follows:

TERMINAL	FUNCTION
1	0-20 PPS (+), 4-20 mA DC (+)
2	0-20 PPS (–), 4-20 mA DC (–)

3–11 SEALING THE TRANSMITTER

3–12 After making power and signal connections, make certain that the power and signal conduits are

Figure 9. Transducer Mounting Constraints (Instruction Manual IDS 500/501 A)



Power and Signal Electrical Connections to Transmitter

sealed. This will prevent water, which may collect in the conduit, from entering the enclosure. A tube of RTV sealant is provided for this purpose.

3–13 To preserve the NEMA 4 (weatherproof and hosedown proof) rating, the Transmitter covers must be properly tightened. The single socket-head screw securing the Electrical Connections Section Cover must be tightened an additional 1⅓ turns after initial seating. The four socket-head screws securing the Electronics Section Cover must be tightened 1¼ turns after initial seating.

Figure 10. Power and Signal Electrical Connections to Transmitter (Instruction Manual IDS 500/501 A)

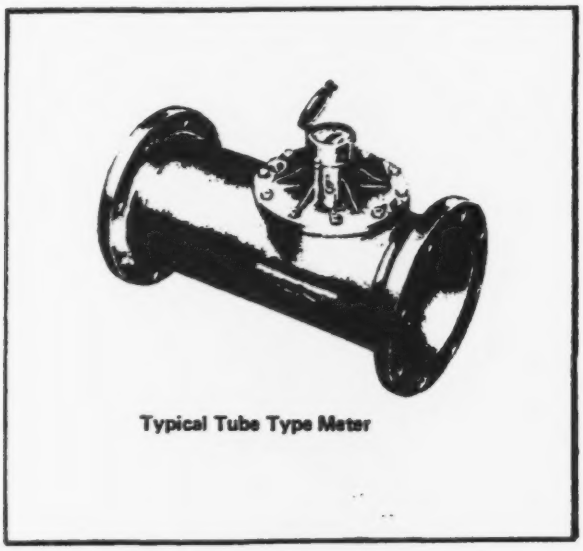


Figure 11. Sparling Magnetic Drive, Tube Type Flow Meter #103 (Product Data Sheet PDS 102)

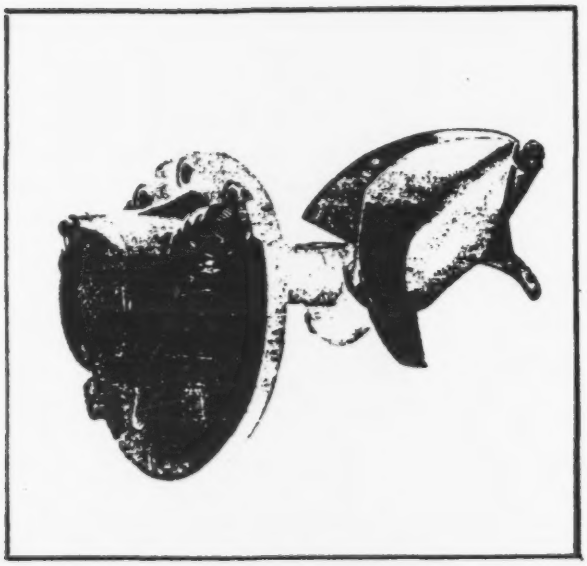


Figure 12. Sparling Electronic Flow Meter #185 (Product Data Sheet PDS 105)

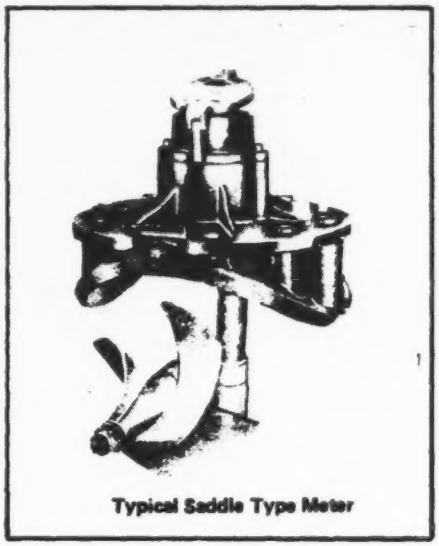


Figure 13.

Saddle type meter Model #103
(Product Data Sheet, Sparling)

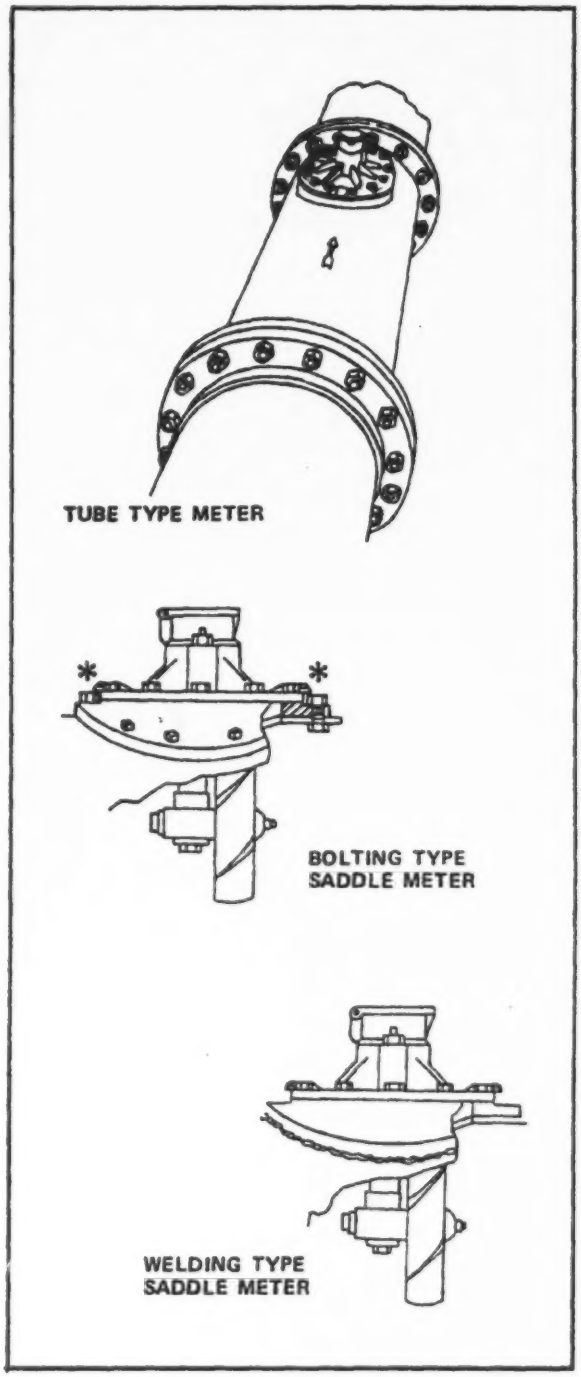


Figure 14. Installation of Tube Type, Saddle Type Sparling Flow Meters (instruction Data Sheet IDS 115)

Portable Weir for Measuring Fish Holding Tank Water Flow

A device for rapidly measuring or adjusting water flow rates in fish hatchery tanks was constructed from a surplus 5-gallon plastic bucket. A slot ½ inch wide and 7 inches long was cut in the side of the bucket to act as a spillway and measuring surface. The weir was calibrated with water flows of 3, 6, 10, 15, and 20 gallons per minute. Each flow rate was allowed to reach its highest level in the slot and then marked with embossing tape. Water flow rates are then easily adjusted without use of ruler and stopwatch in a quick, continuous operation. This weir is also handy for measuring flow rates to fish egg incubators.

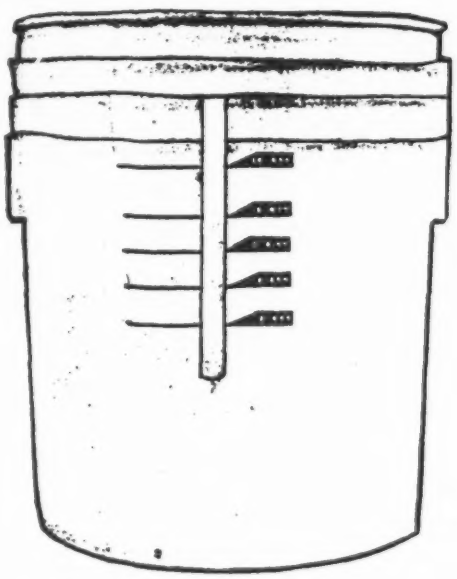


Figure 15. Calibrated Bucket for measuring small flows (metric units not used here) James N. Hanson - Bureau of Sportfisheries & Wildlife, 1974)

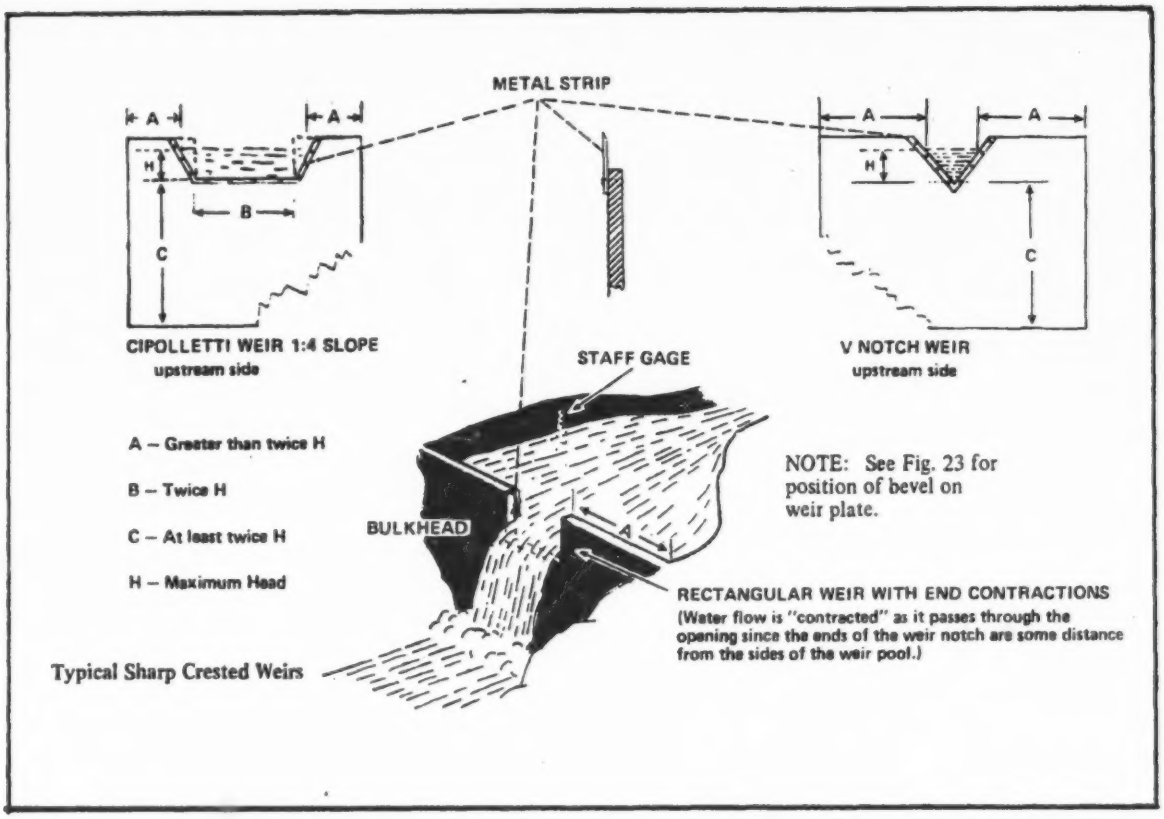


Figure 16. Different shapes of weirs. (Stevens Water Resources Data Book, 3rd edition, 1978)

Figure 17. Rectangular Contracted Weir - Robertson Creek

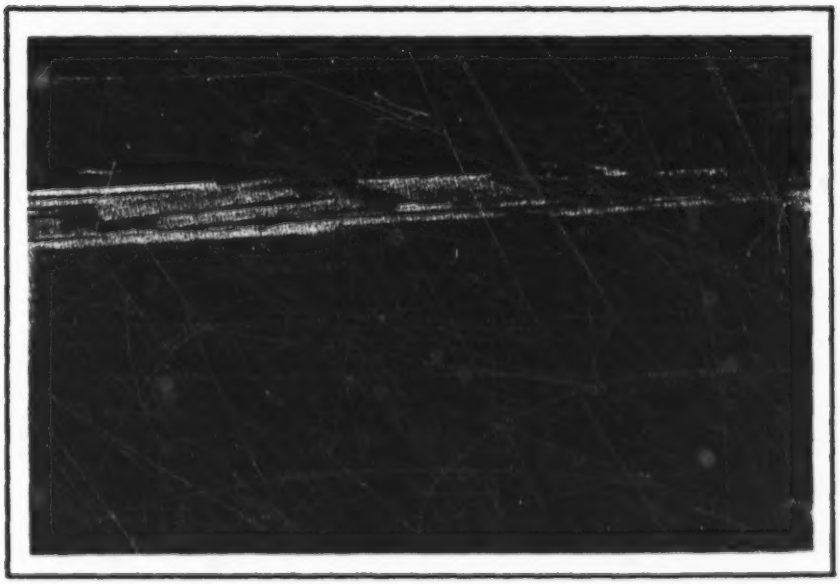


Figure 18. Rectangular Contracted Weir - Puntledge River - Lower Site

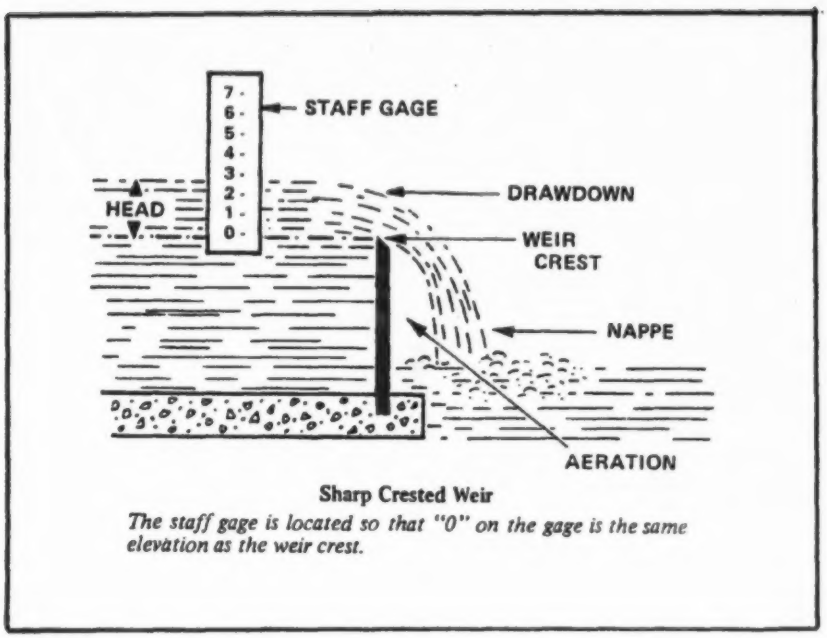


Figure 19. Sharp Crested Weir (Steven Water Resources Data Book, 3rd edition, 1978)

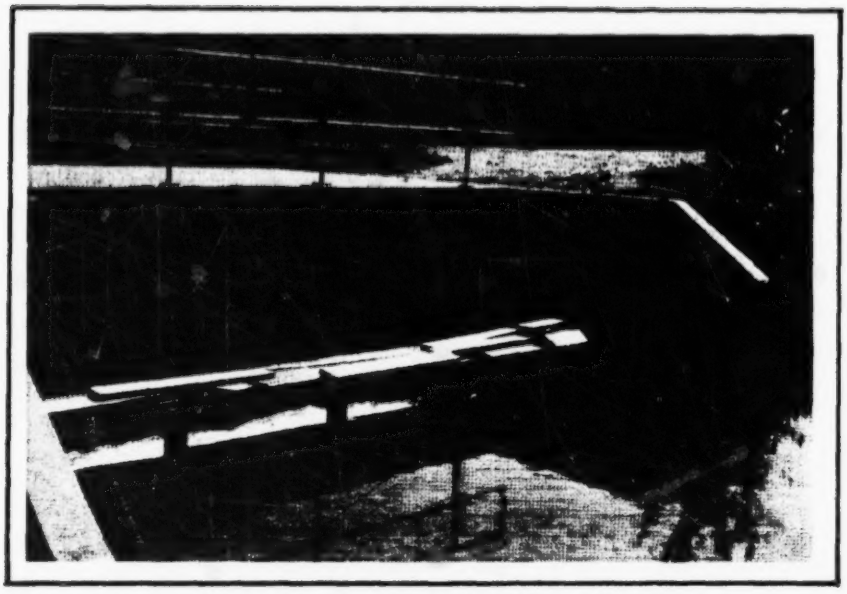


Figure 20. Rectangular Suppressed Weir, semi-natural channel at Puntledge River

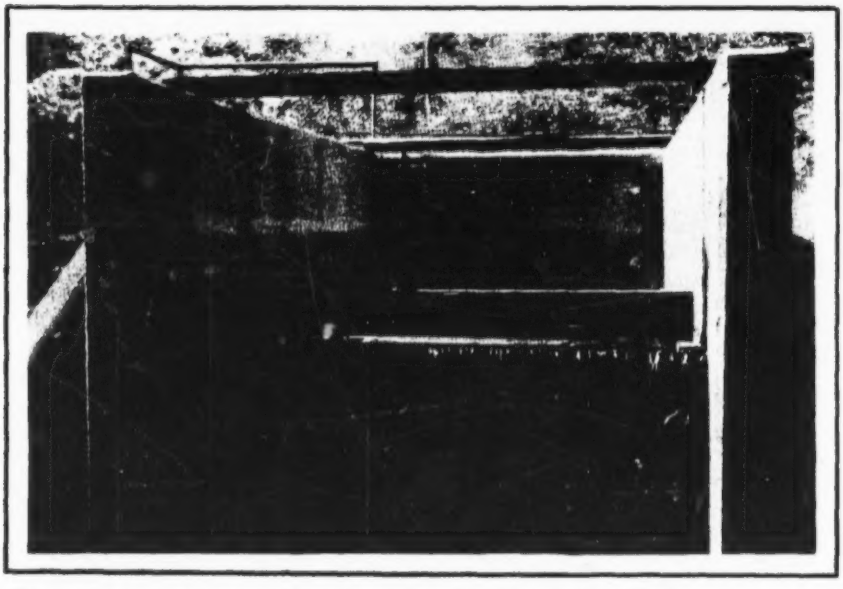


Figure 21. Rectangular Suppressed Weir, chinook rearing channel, Little Qualicum River

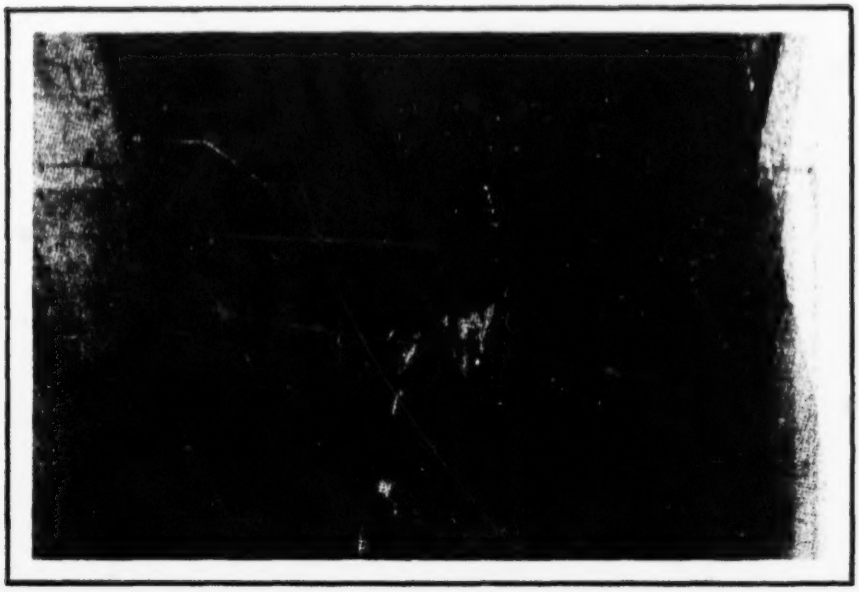


Figure 22. 90^{o} V Notch Weir, Burrows Pond discharge, Quinsam River (note leakage)

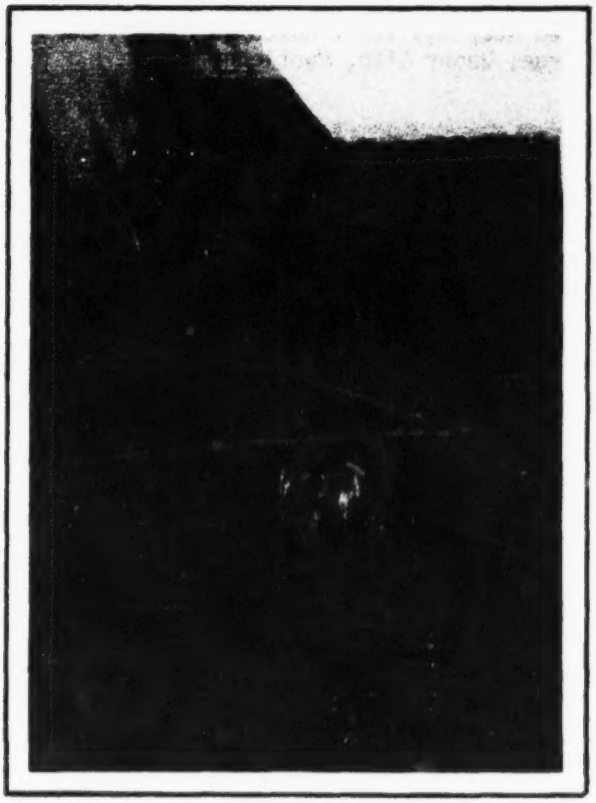


Figure 23. 90^{o} V Notch Weir, Burrows Pond discharge, Quinsam River

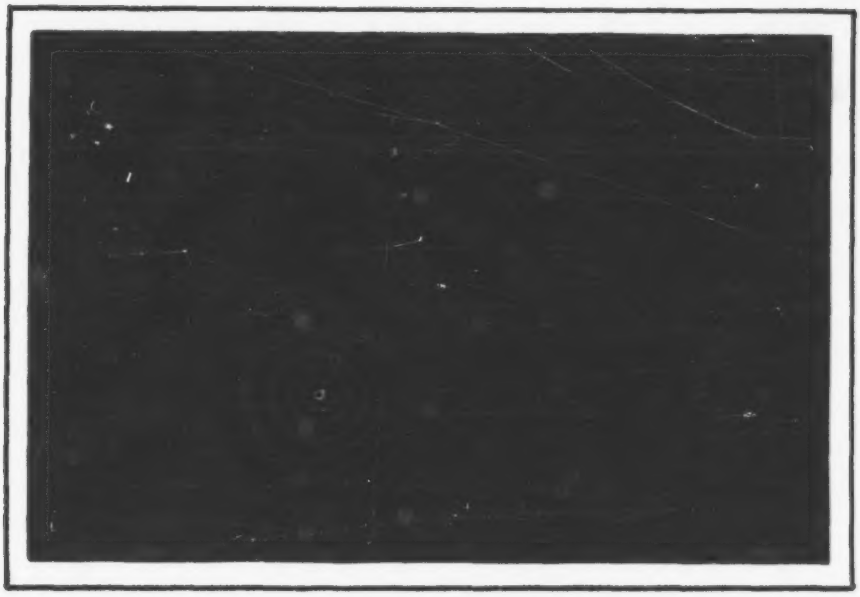


Figure 24. Modified stoplog, 90° V Notch Weir, Burrows Pond discharge, Upper Site, Puntledge River.

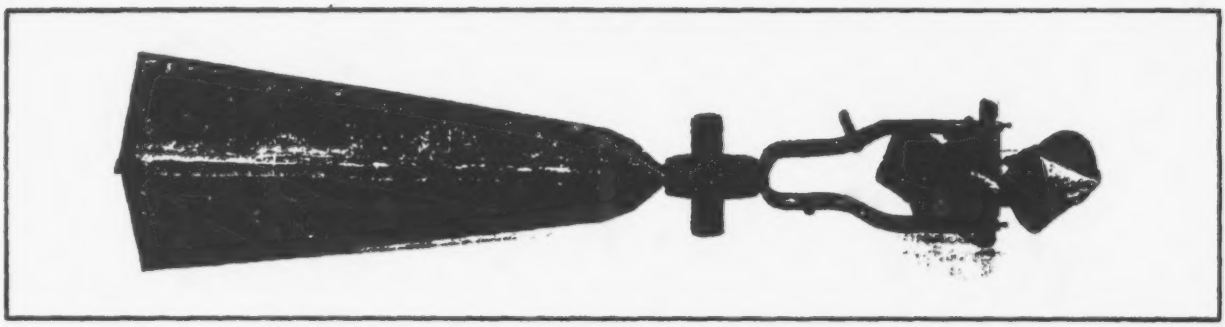


Figure 25. The original Price current meter, built by Price and four mechanics at Paducah, Kentucky, in 1882 (Water Current Meters, Frazier, 1974)

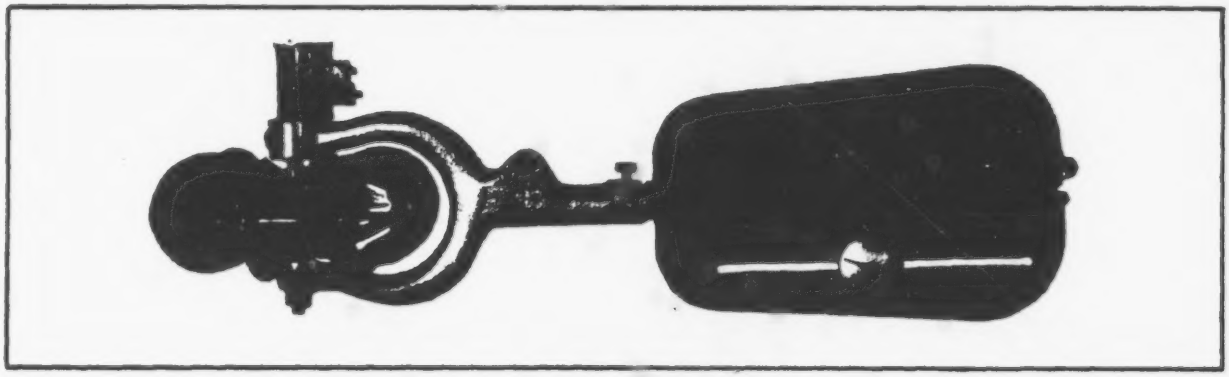


Figure 26. Modern version of Price Pattern, Gurley Current Meter Type AA (Water Current Meters, Frazier, 1974)

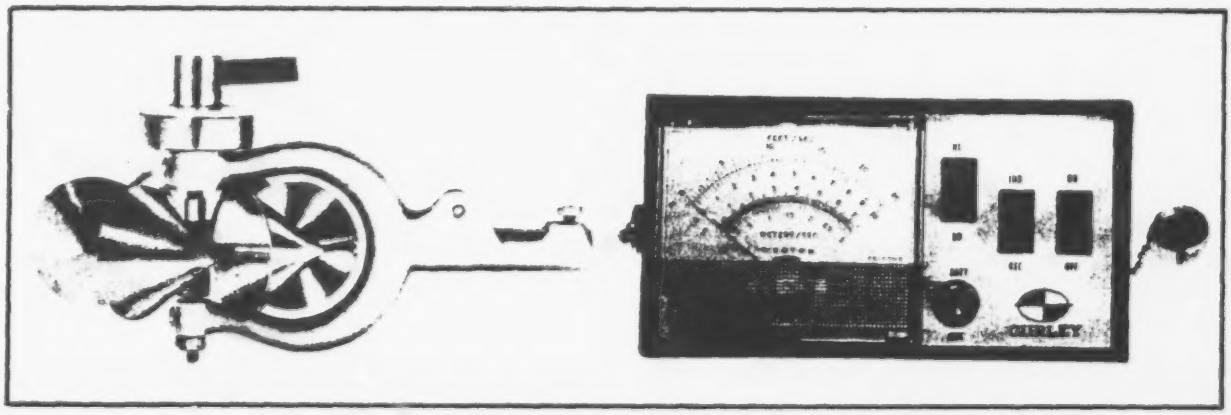


Figure 27. #665 Direct Reading Current Meter (Teledyne Gurley Bulletin 700)

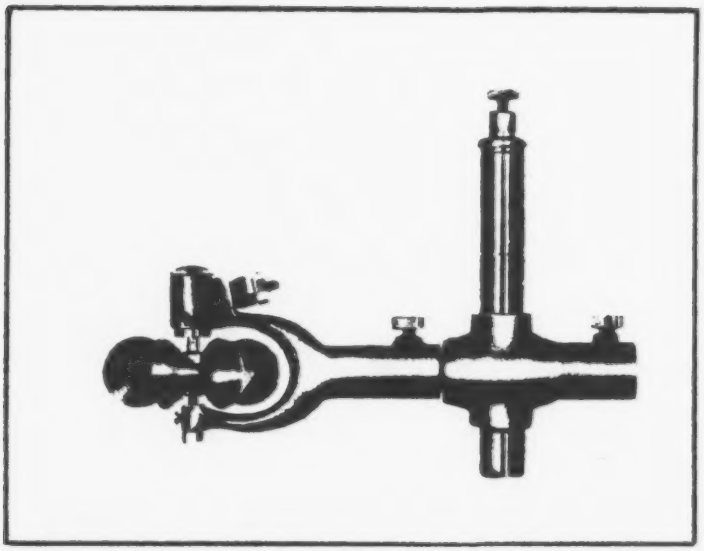


Figure 28. Pygmy Type Gurley Meter (Teledyne Gurley Bulletin 700)

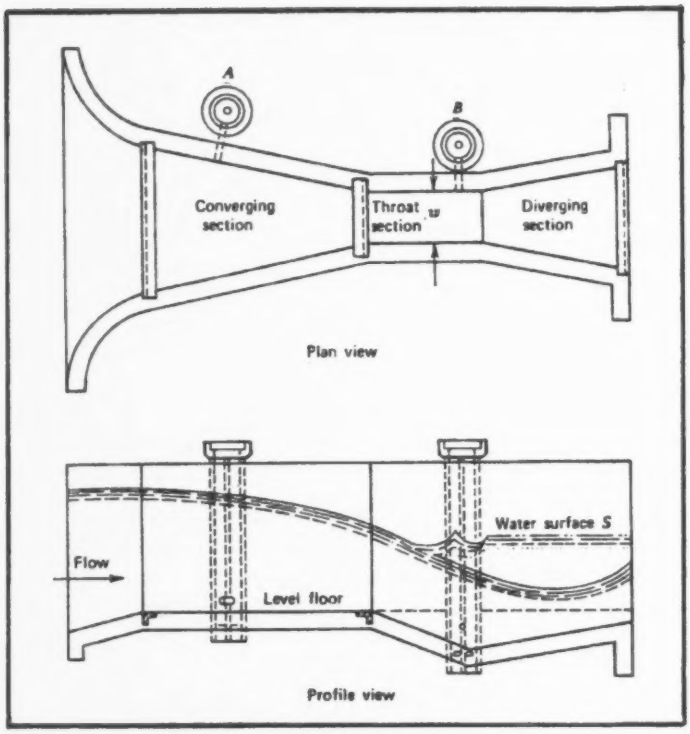


Figure 29. Parshall Flume Dimensions (Aquacultural Engineering, 1977)

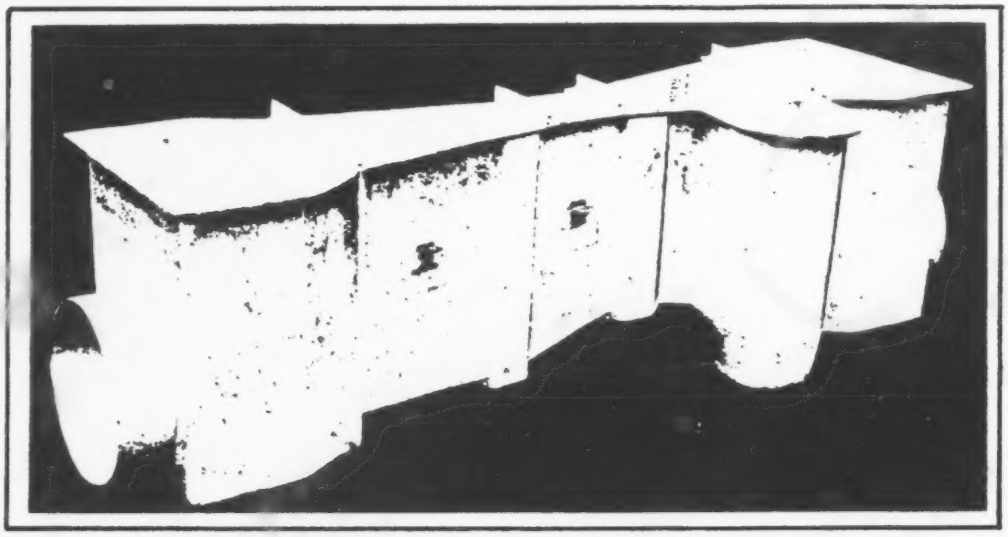


Figure 30. Prefabricated Parshall Flume for use in a pipeline (Sirco Product Bulletin)

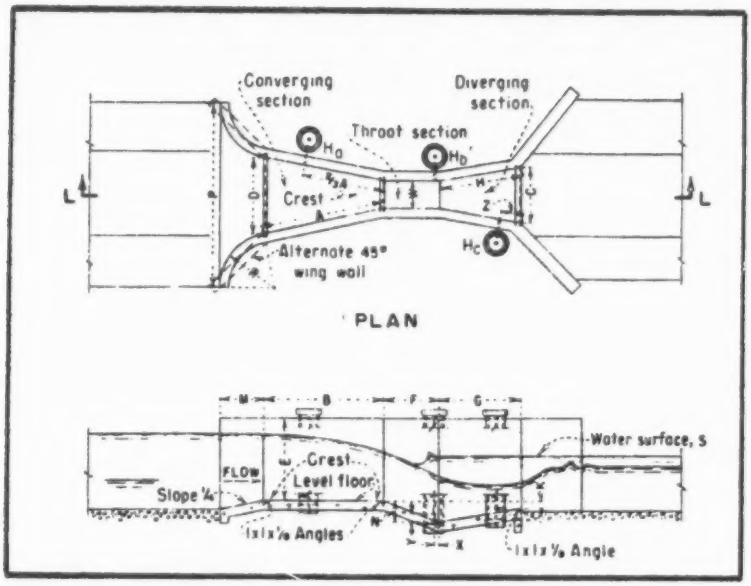


Figure 31. Venturi Meter (Water Measurement Manual, 1967)

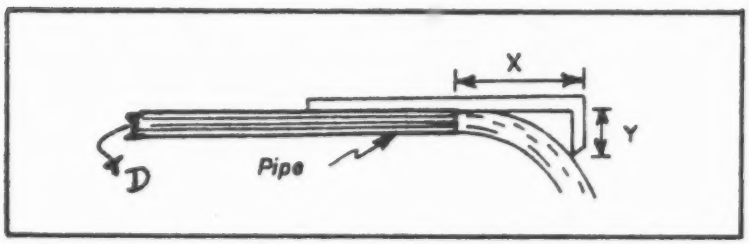


Figure 32. Flow from horizontal pipeline, showing co-ordinates for trajectory method of calculating discharge.

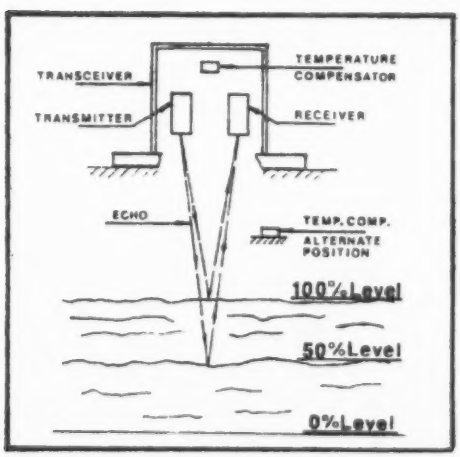


Figure 33. Position of the Sirco-Ultra Sonic Meter, shown in position above open channel

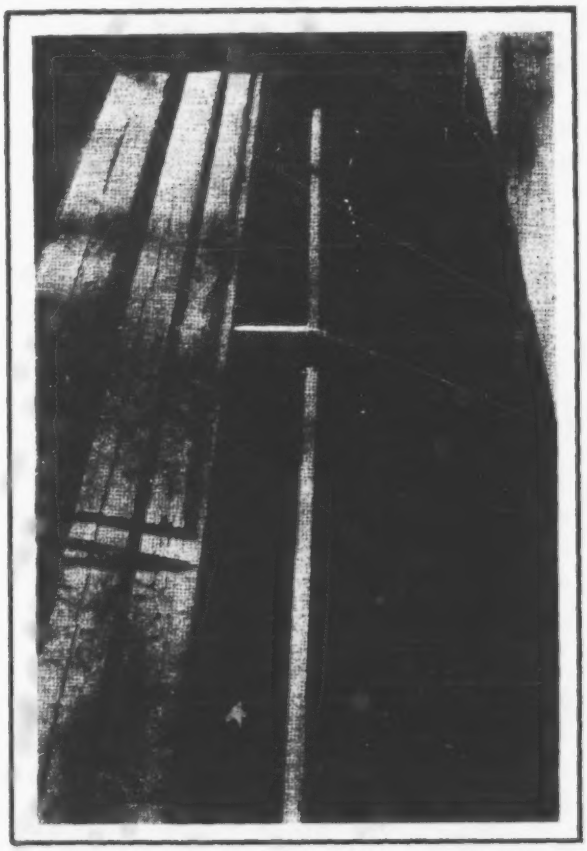


Figure 34. Rectangular Suppressed Weir (non standard), coho raceways, Puntledge River. (Note near submergence of nappe)

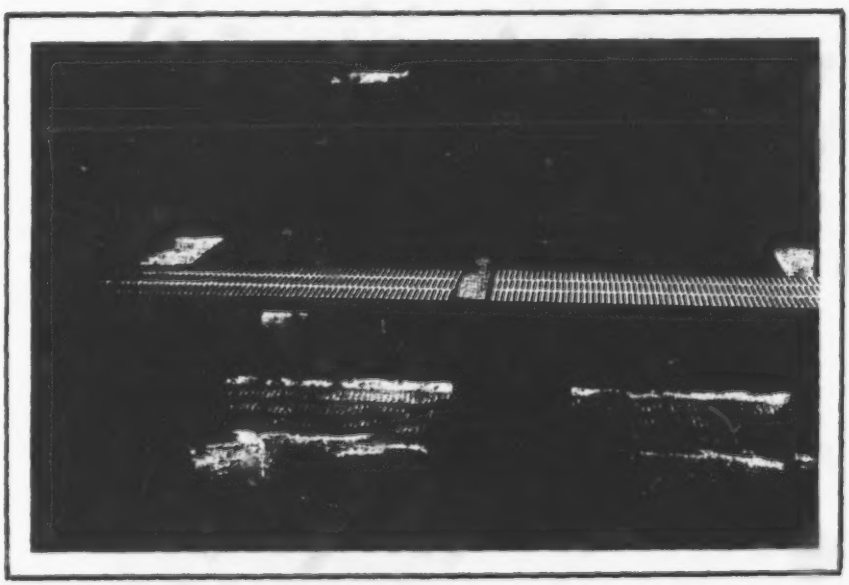


Figure 35. Rectangular Suppressed Weir, Robertson Creek earth channel IA (Note plywood boxes on the upstream sides of this weir)